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REGIONAL TOPOGRAPHY, PHYSIOGRAPHY, AND GEOLOGY OF THE NORTHERN GREAT PLAINS

William R. Keefer

Northern Great Plains Resource Program

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1974

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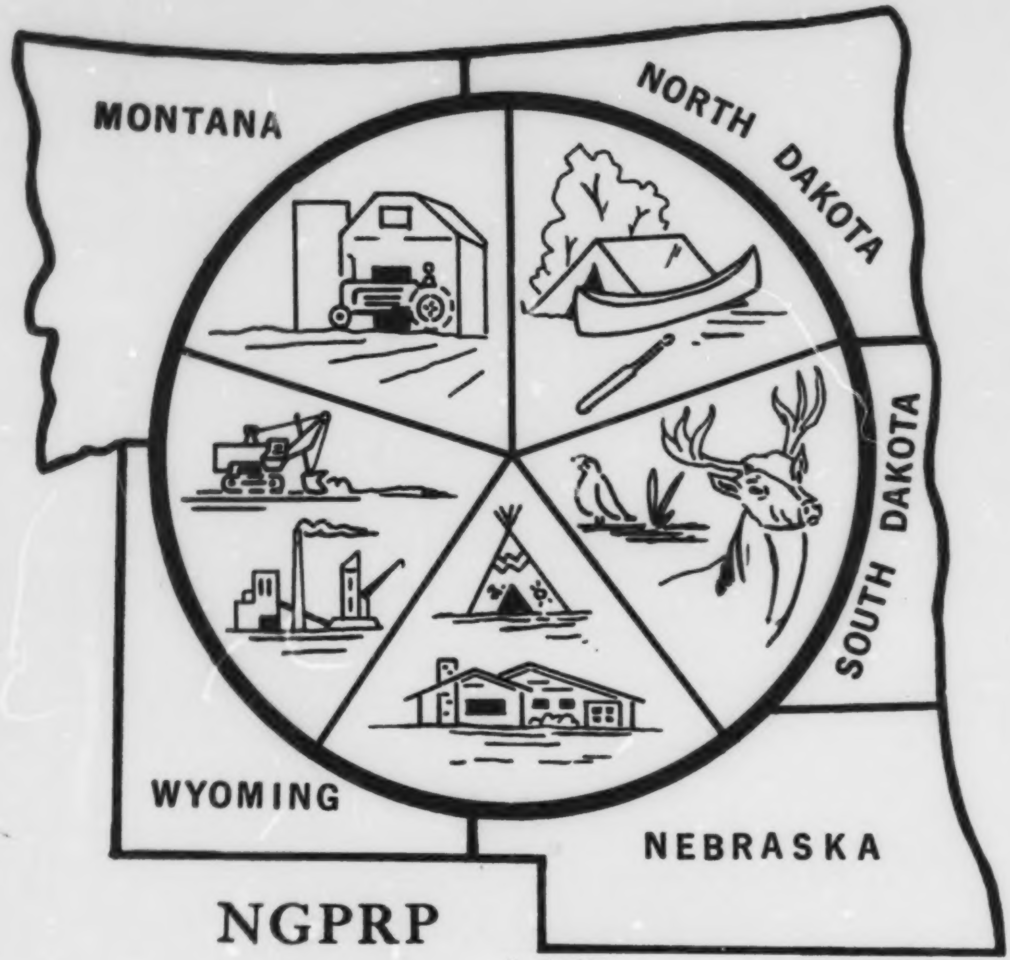
REGIONAL GEOLOGY WORK GROUP REPORT



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Analyzes the topography, physiography and geology of a 63 county area in North Dakota, Montana, Wyoming and South Dakota. Geologic maps are included. In addition 7½ minute quadrangle slope maps are included for 5 selected sites that are representative of the areas that are likely to be impacted with accelerated coal development in the Northern Great Plains. These maps are provided as tools for planning transportation facilities, utility corridors, siting of mines and related facilities, controlling erosion, determining reclamation potential, and preparation of mining plans.

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By
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1974

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This report is preliminary
and has not been edited
or reviewed for conformity
with U.S. Geological Survey
standards and nomenclature.

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REGIONAL TOPOGRAPHY, PHYSIOGRAPHY, AND GEOLOGY OF THE NORTHERN GREAT PLAINS

By

William R. Keefer
U.S. Geological Survey

Introduction

This report was prepared as part of the Northern Great Plains Resources Program. Its primary purpose is to provide general descriptions of the topography, physiography (land forms), and geology of the Northern Great Plains region and adjoining areas in northeastern Wyoming, eastern Montana, western North Dakota, and northwestern South Dakota. The discussions focus chiefly on the Powder River and Williston basins, which are the principal geologic features and contain the bulk of the coal, oil, gas, uranium, and other resources in the 146,000 square mile (378,000 sq. km) study area.

Topography and Physiography

The Northern Great Plains region lies almost wholly within the Great Plains physiographic province (plate A-1; Fenneman, 1931, p. 1-91). Elements of the Middle Rocky Mountains, Wyoming Basin, and Southern Rocky Mountains provinces are included along the west and southwest margins and a segment of the Central Lowland province is included along the northeast margin. Except for the extreme northeast corner, which is drained by the northward-flowing Souris River, the entire region is within the drainage basins of the eastward- and southeastward-flowing Missouri River and a principal tributary, the northeastward-flowing Yellowstone River. The North Platte River, near the south edge, flows eastward into the main stem of the Platte River in central Nebraska, and thence into the Missouri River at the east edge of Nebraska.

The northeast corner of the Northern Great Plains study area, which is within the Western Lake Section of the Central Lowland province, is characterized by nearly flat plains surrounding the Souris River and Des Lacs River Valleys. Elevations rise from about 1,500 feet[1] above sea level along the valley floors to 2,000 feet at the margin of the Turtle Mountains on the northeast and to 1,700-2,000 feet along the foot of the Missouri Escarpment on the southwest. The Turtle Mountains are a group of hummocky hills generally less than 200 feet high; maximum elevations reach 2,400 to 2,500 feet above sea level in that area.

The boundary between the Great Plains and Central Lowland physiographic provinces is marked by the Missouri Escarpment, a conspicuous linear topographic feature extending northwest across the northeast part

[1] To convert feet to meters, multiply feet by .3048.

of the study area (plate A-1). The east-facing slope rises from elevations of 1,700-2,000 above sea level along the base to 1,900 to 2,200 feet at the top. Westward, the escarpment levels off onto the Missouri Plateau, which is the name commonly given to that part of the Great Plains province that lies within the Northern Great Plains study area (sometimes referred to also as the Upper Missouri Basin).

The eastern segment of the Missouri Plateau is a 15- to 25-mile wide strip of extremely irregular terrain which abounds with hills, lakes, ponds, and swamps indicative of the glacial origin of the landscape. This strip, cutting diagonally northwest across central North Dakota, is commonly referred to as the Coteau du Missouri (Hills of the Missouri). To the southwest, the terrain slopes downward to the valley of the Missouri River, an ice-marginal stream whose present position was determined by continental glaciers advancing from the north and northeast some 10,000-15,000 years ago.

The Missouri Plateau stretches westward and southwestward across western North Dakota and northwestern South Dakota into the broad plains region of eastern Montana and northeastern Wyoming, skirting the Black Hills in west-central South Dakota (plate A-1). The landscape is dominated by plains and low-lying hills and tablelands, interrupted here and there by entrenched river valleys and by isolated uplands, buttes, and mesas. Elevations rise gradually from about 2,000 feet above sea level at the east edge of the Missouri Plateau to 5,000-6,000 feet at the foot of the bordering mountain ranges along the west and southwest margins. Except for the areas covered by glacial deposits (see plate A-3), the surface rocks throughout are chiefly soft, easily eroded sandstones and shales.

Geologically, that part of the Northern Great Plains lying in western North Dakota, northwesternmost South Dakota, and easternmost Montana is referred to as the Williston basin, and that part lying in southeastern Montana and northeastern Wyoming (west of the Black Hills) is referred to as the Powder River basin (see plate A-4). Both features are major downfolds, separate and distinct from adjacent geologic structures. The Williston basin has little topographic or physiographic expression, but the Powder River basin is bounded by extensive uplands along parts of its east, south, and west margins. To the north and northeast, however, the terrain of the Powder River basin merges with, and cannot be distinguished from, the remainder of the Missouri Plateau.

The Black Hills are an isolated mountain range surrounded by other elements of the Missouri Plateau; only the north end of the range is included in the Northern Great Plains study area (plate A-1). Elevations range from 4,000 feet above sea level in the foothills to nearly 7,000 feet along the crest. The range exhibits a central core of irregularly dissected crystalline rocks flanked in the foothills areas by concentric ridges and valleys that have been eroded from an alternating sequence of resistant and non-resistant sedimentary rocks.

The northwestern part of the Laramie Mountains, which are an element of the Southern Rocky Mountains physiographic province, extends into the south edge of the study area (plate A-1). Elevations rise abruptly from 5,000 feet along the floor of the Powder River Basin and the valley of the North Platte River to nearly 9,000 feet along the crest of the range. The north- and northeast-facing slopes are deeply faceted by numerous tributaries of the North Platte. Casper Mountain, at the extreme northwest tip of the Laramie Mountains, stands 2,000 feet above the basin floor south of the city of Casper, and descends westward onto the plains of the adjacent Wyoming Basin province.

The dividing line between the Great Plains and Wyoming Basin provinces is not marked by any prominent topographic or physiographic feature. It is more readily defined, however, on the basis of geologic structure. Extending between the Laramie Mountains and the Bighorn Mountains to the northwest is a broad upfold known geologically as the Casper arch (see plates A-1 and A-4). This feature separates the downfolded Powder River basin on the east from the similarly downfolded Wind River basin (part of the Wyoming Basin Province) to the west. The crest of the arch is occupied in several places by sharply folded, smaller anticlines, and a northwest-trending line connecting these features is arbitrarily used as the boundary between the two major physiographic provinces. It should be noted that the Powder River heads west of this line in the easternmost part of the Wind River Basin. The terrain extending across the Casper arch, generally less than 6,000 feet above sea level, is flat to gently rolling, but locally it is eroded into prominent irregular "breaks" particularly near the south end of the Bighorn Mountains.

The Bighorn Mountains, one of the major ranges of the Middle Rocky Mountains physiographic province, extends northwest along the southwest edge of the Northern Great Plains study area for about 150 miles (plate A-1). Rising from 5,000-6,000 feet above sea level in the foothills areas to more than 13,000 feet at the crest, the Bighorns form an imposing mountain barrier between the Powder River Basin on the east and the Bighorn Basin on the west. In gross aspect, the range contains a massive core of crystalline rocks surrounded by gently to steeply inclined sedimentary rocks. The east slope, facing the Powder River Basin, is steep and rugged for the most part, and is cut by many deep, narrow canyons. Except for the middle third of the range, which is precipitous and highly glaciated, the upland surfaces extending across the top are flat to gently rolling. Near the north end, at the Wyoming-Montana state line, the Bighorn River has cut a gorge through the mountains and flows out of the Bighorn Basin onto the Great Plains; Yellowtail Dam and Reservoir are located within this gorge.

The Pryor Mountains are a small, detached mountain uplift which can be considered physiographically as the northwest continuation of the Bighorn Mountains. The uplift appears as a dissected plateau, with sedimentary rocks covering both the top and flanks. Elevations range from 5,000 feet around the base to nearly 9,000 feet in the higher parts.

North of the Bighorn Mountains and Pryor Mountains, and extending to the Canadian border, the landscape of the Northern Great Plains is dominated by broad to sharply entrenched river valleys (chiefly, the Yellowstone, Musselshell, and Missouri Rivers) and by extensive low, moderately to deeply dissected interstream divides. The Big Snowy Mountains, whose southeast-facing slopes rise abruptly 3,000 feet above the plains in the northwest corner of Golden Valley County, Montana, are the only uplands of consequence across this area.

A map prepared by Edwin H. Hammond (U.S. Geological Survey, 1970, p. 61-64; Hammond, 1964, p. 11-19) showing broad-scale land form characteristics in the United States was adapted for use in the present study to provide generalized information on two basic attributes of the landscape--slopes and local topographic relief--across the North Great Plains region (plate A-2). The boundary lines plotted on plate A-2 are essentially those published by Hammond on smaller scale maps; however, some modifications were made by the writer following visual inspection of the two-degree, 1:250,000 topographic maps of the region. The unit area chosen by Hammond as the basis for his classification was a six-mile square, which, in the case of the Northern Great Plains, corresponds to the area of an individual township.

Except where abrupt changes in slope angles and topographic relief are involved, such as juxtaposed plains and mountains, the differences between the various land form categories shown on plate A-2 are not great. The boundaries are therefore gradational in many places, and small areas exhibiting characteristics of one land form type may be included with another type. However, the categories as presently delineated are considered to be representative of much the greater parts of the land surface included within them. As expected, certain boundary lines on plate A-2 coincide closely to boundaries between major physiographic provinces and other large physical features as shown on plate A-1. The predominance of plains and tablelands is also evident throughout the region. Of particular note are the extensive areas classified as "open high hills" (labelled C4 on plate A-2), indicating rough, broken terrain where the land surface has suffered moderate to deep erosion as exemplified by the prominent badlands adjacent to the Little Missouri River in west-central North Dakota.

The classification of land forms has a variety of uses. It provides an index to general terrain conditions which may exert a significant influence on the cross-country "movement" of people and things, such as the construction of a transmission line. Knowledge of land forms likewise may be used in evaluating the degree of difficulty to be expected in reshaping surface-mined land so that it will conform closely to the surrounding, undisturbed land surface. Deeply dissected badlands would be extremely difficult to reshape, for example, whereas irregular plains would be less difficult. The scenic or aesthetic values of a given area are, of course, directly dependent upon its landscape characteristics.[2]

[2] Detailed slope characteristics of selected 7-1/2-minute quadrangles are given in Appendix C of this report.

Geology

General

A geologic map (plate A-3) and a structure contour map (plate A-4) portray the principal geological characteristics of the Northern Great Plains region. The geologic map is primarily a bedrock map, and, except for a few areas, does not show the narrow strips of surficial deposits (sand, gravel, silt, and clay) that commonly occur in river and other stream valleys. Glacial deposits are shown in a large area in the northeast corner of the study area, however, where they almost completely bury the bedrock units. Extensive deposits of glacial drift are also present in a 20- to 100-mile wide strip that lies to the southwest. Bedrock is only intermittently exposed within this strip, and formation contacts are inferred throughout much of it. Because of the small scale of the geologic map (1:1,000,000; 1 inch equals approximately 16 miles), two or more geologic formations have been combined into single units in many places for adequate map representation. The individual formations contained in each map unit are shown in the geologic map explanations (plate A-3), and general descriptions are given in Appendix A. Major stratigraphic and geologic time divisions are listed in Appendix B.

The structure contour map (plate A-4) reflects the major geologic structures of the region by means of contour lines drawn on top of the Fall River Formation in the Powder River Basin and adjacent areas in northeastern Wyoming and southeastern Montana, and on top of the Kootenai Formation or the equivalent Cloverly Formation elsewhere. All these formations are Early Cretaceous in age, but the Fall River occupies a stratigraphic position that is somewhat higher than either the Kootenai or the Cloverly. The contour interval is 1,000 feet, except locally where only 5,000-foot intervals are shown; contours above 5,000 feet have not been drawn.

The major geologic features in the Northern Great Plains region--the Williston and Powder River basins--are extensive downfolded structures which contain thick sequence of sedimentary rocks and the bulk of the mineral resources that are of special interest to the present study. In particular, these basins were the sites of accumulation of widespread coal deposits during the Paleocene and Eocene epochs of the Tertiary period (50-60 million years ago; see Appendix B), and the downwarping has preserved these deposits from subsequent erosion over most of both basin areas. A comparison of the structure contour map (plate A-4) with a coal map of the Northern Great Plains (Averitt, 1974) readily shows the influence of basin structure on the present distribution of coal deposits throughout the Northern Great Plains region.

Rocks

Rocks of all geologic systems occur in the Northern Great Plains region. The oldest are represented by the Precambrian crystalline rocks ("basement complex") in the cores of the Black Hills and Hartville uplift, and the Laramie, Granite, Bighorn, Pryor, and Big Snowy Mountains (plate A-3). Flanking the uplifts are layers of progressively younger sedimentary rocks which are upturned and eroded near the mountain fronts, but which flatten toward the basin interiors. These rocks range in age from Cambrian to late Tertiary. The strata forming the surface rocks over much of the Powder River and Williston Basins are early Tertiary (Paleocene and Eocene) in age. They were once covered by several thousands of feet of younger Tertiary rocks most of which have since been removed by erosion. The youngest sedimentary units in the region are the unconsolidated alluvial, glacial, and other surficial deposits.

Precambrian rocks exposed in the mountain areas are chiefly resistant, fine to coarsely crystalline igneous and metamorphic rocks. Granite and granite gneiss predominate; one exception is in the core of the Big Snowy Mountains of central Montana, where hard compact shales of the Precambrian Belt Supergroup are locally exposed. Igneous rocks of early Tertiary age occur in places in the Black Hills and along the north edge of the Granite Mountains.

A great variety of rock types comprise the sedimentary formations of the region (Appendix A). Individual formations also vary considerably in character from one place to another. In general, there is a gradual transition from the more resistant limestone, dolomite, and sandstone beds in the lower parts of the succession (Cambrian through Lower Cretaceous) to the less resistant sandstone and shale beds in the higher parts (Upper Cretaceous and Tertiary). Most of the sedimentary rock units that crop out along the west, south, and east margins of the Powder River Basin project beneath the basin without interruption. Maximum combined thickness of all strata is about 23,000 feet in the structurally deepest parts of the basin (Denson, oral commun., 1974). The sedimentary sequence occupying the Williston Basin has a maximum thickness of about 16,700 feet (Sandberg, 1962, p. 18), and contains several formations ranging in age from Late Ordovician to Early Mississippian that are not represented in surface exposures.

The Fort Union Formation of Paleocene age, which is the most widely exposed sedimentary rock unit in the Northern Great Plains region, is the principal coal-bearing formation. In many places it can be subdivided into two or more members for detailed geologic mapping and for more precise coal bed correlation and resource evaluation. Coal beds are generally thickest, most numerous, and most widespread in the upper part of the sequence. In the Gillette area of central Campbell County, Wyoming, for example, nearly a dozen coal beds, with combined thicknesses of more than 300 feet locally, have been identified in the upper 1,000-1,200 feet of the Fort Union and traced over several hundered square miles (Denson, Keefer, and Horn, 1973). The overlying Wasatch Formation of Eocene age also contains coal beds of economic interest in several parts of the Powder River Basin. Because of the slight inclination of the sedimentary strata along most basin margins (see following discussion of structure) several of the Fort Union and Wasatch coal beds remain close to the ground surface over wide areas.

Glacial deposits, consisting of gravel, sand, silt, and clay, occur in ground and end moraines and in outwash plains. The deposits are 100 to 200 feet thick over much of the glaciated area, but locally they attain thicknesses of 500 to 600 feet along buried, preexisting stream channels (Bluemle, 1971; U.S. Geological Survey and others, 1973, p. 42).

Structure

The Williston and Powder River basins, as mentionedpreviously, are broad regional downfolds which dominate the geologic structure of the Northern Great Plains. The Williston basin is a nearly symmetrical, elliptically shaped basin whose limbs are inclined very gently (50 to 65 feet per mile) toward a central, structurally low area in northwestern North Dakota (marked by the minus 3,500-foot contour on plate A-4; Sandberg, 1962, fig. 4). In contrast, the Powder River basin is an elongate, markedly asymmetrical feature with a gentle east limb (150 feet per mile) and a relatively steep west limb (500 to 600 feet per mile) dipping toward a deep trough line that lies near the west basin margin (marked by the minus 9,000-foot contours on plate A-4). Other large structural downfolds in the Northern Great Plains study area include the Bull Mountains basin in central Montana and the southeast arm of the Wind River basin in central Wyoming.

The 5,000-foot structure contour lines outline the mountain ranges and other major uplifts of the region (plate A-4). In some places the structural relief between adjacent mountain and basin structures is enormous, such as between the crest of the Bighorn Mountains and the trough line of the Powder River basin where it exceeds 25,000 feet.

Many subsidiary geologic structures--anticlines, synclines, and faults--occur throughout the region; only a few are labelled on plate A-4. Nesson and Cedar Creek anticlines are prominent features on the northeast and southwest flanks of the Williston basin, respectively. Except along the west limb of Cedar Creek anticline, where dips range from 4 to 30 degrees (and locally exceed 30 degrees), the sedimentary strata flanking the folds are inclined generally less than 3 degrees (Sandberg, 1962, p. 116). At the west side of the basin, Poplar and Bowdoin domes are also gently folded features. All the anticlines mentioned above are locally oil- and gas-bearing.

The south and southwest limbs of the Sheep Mountain and Blood Creek synclines are considered to form the southwest edge of the Williston basin (Sandberg, 1962, fig. 1). Adjoining features include Porcupine Dome and a broad, structurally positive area extending northwest from the Black Hills. The latter, sometimes called the Miles City arch (Mallory, 1972, p. 37), forms the boundary between the Williston and Powder River basins. Porcupine Dome and the Big Snowy Mountains to the west are part of what is commonly referred to as the Central Montana uplift.

Anticlines and synclines occur in considerable numbers across the Powder River basin, but the small scale and generalized character of the structure contours shown on plate A-4 do not reflect them in detail in most cases. Many of the oil and gas fields in the basin are located on anticlinal structures. However, numerous large petroleum accumulations have been discovered in recent years along the gentle east flank of the basin where stratigraphic conditions in Lower Cretaceous sandstones (most notably, the Muddy Sandstone Member of the Thermopolis Shale) form the trapping mechanism rather than anticlinal folding.

The Casper arch is the structural boundary between the Powder River basin and the Wind River basin to the southwest. The southwest margin of this feature is marked by an extensive fault zone. Prominent fault zones also extend along the north edge of the Laramie Mountains, in places along the east flank of the Bighorn Mountains, and on the southwest side of Cedar Creek anticline. Faults of lesser magnitude occur in many other parts of the region, but only a few are plotted on plates A-3 and A-4. Most faults are inactive at the present time.

Geologic History

Pre-uppermost Cretaceous sedimentary rocks originated primarily in broad, relatively shallow epicontinental seas which advanced and retreated across the present site of the Northern Great Plains many times during the Cambrian and ensuing geologic periods. Beginning with the deposition of the Lance and Hell Creek Formations in latest Cretaceous time, however, there was a shift from predominantly marine to predominantly nonmarine sedimentation which coincided with the advent of major mountain-building movements throughout much of the Rocky Mountain chain. Many of the major structural features of the Northern Great Plains and adjoining regions to the west commenced to form at this time, and structural deformation continued through the early part of the Tertiary period in most places.

As deformation proceeded, vast amounts of clastic material were eroded from the rising mountains and deposited in the intervening, subsiding basins. The basin floors remained close to sea level, and subtropical conditions prevailed during most of the Paleocene and early Eocene epochs. At times large segments of the basins were covered by extensive swamps supporting lush growths of vegetation, resulting in the widespread coal deposits now present in the Fort Union and Wasatch Formations.

The basins continued to fill with sediments during middle and late Tertiary time, but large parts of these deposits were removed by erosion prior to the close of the period. Continental glaciers advancing from the north and northeast spread blankets of glacial debris across the northeastern part of the Northern Great Plains in Quaternary time.

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APPENDIX A

SEDIMENTARY FORMATIONS IN THE NORTHERN GREAT PLAINS

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
A. NORTHEASTERN MONTANA			
Sources of data: Collier (1917); Jensen and Varnes (1964); Witkind (1959).			
Alluvium----------------	10±	Sand, gravel--------------------	Unconsolidated.
Glacial deposits--------	15±	Clay, silt, sand, gravel--------	Do.
Flaxville Formation-----	20±	Sand, gravel--------------------	Generally unconsolidated.
Fort Union Formation----	2,000+	Sandstone, siltstone, claystone-	Many thin lignite beds.
Hell Creek Formation----	250±	Claystone, siltstone, shale, sandstone.	
Fox Hills Sandstone-----	35-145	Claystone, siltstone, and sandstone at base overlain by massive sandstone.	
Bearpaw Shale-----------	800-1,140	Shale---------------------------	Many thin bentonite beds.
Judith River Formation--	400	Sandstone, claystone------------	
Claggett Shale----------	750	Shale---------------------------	
B. BIG SNOWY MOUNTAINS, BULL MOUNTAINS BASIN, AND ADJACENT AREAS IN CENTRAL MONTANA			
Sources of data: Foster (1956); Gardner (1950); Mallory (1972); Reeves (1931); Wolsey, Richards, and Lupton (1917).			
Alluvium----------------	10±	Sand, gravel, silt--------------	Unconsolidated.
Terrace deposit---------	10±	---do---------------------------	Do.
Fort Union Formation----	1,900	Shale, claystone, sandstone-----	Many coal beds.
Hell Creek Formation----	700-1,500	Sandstone, claystone, shale-----	Locally includes Lennep Sandstone at base.
Bearpaw Shale-----------	1,000+	Shale---------------------------	Some thin bentonite beds.
Judith River Formation--	200-400	Sandstone, siltstone, shale-----	
Claggett Shale----------	200-600	Shale---------------------------	Some thin bentonite beds.
Eagle Sandstone---------	200-525	Sandstone, shale----------------	
Colorado Shale----------	2,250	Shale, sandstone----------------	Many thin bentonite beds.
Kootenai Formation------	230-500	Shale, sandstone, limestone-----	Structure contour horizon (plate A-4).
Morrison Formation------	125-200	Shale, claystone, siltstone, sandstone.	
Ellis Group-------------	130-400	Limestone, shale, sandstone-----	Some gypsum.
Quadrant Formation------	0-50	Limestone, shale----------------	
Amsden Formation--------	100-200	Limestone, dolomite, shale------	
Big Snowy Group---------	800	Shale, sandstone----------------	
Madison Group-----------	1,600	Limestone-- --------------------	
Snowy Range Formation---	425	Limestone, shale, siltstone-----	
Pilgrim Limestone-------	225	Limestone, shale----------------	
Wolsey and Park Shales--	300	Shale, limestone----------------	
Flathead Sandstone------	175	Sandstone, conglomerate---------	

C. BIGHORN MOUNTAINS, PRYOR MOUNTAINS, AND WESTERN POWDER RIVER BASIN

Sources of data: Hose (1955); Keefer and Van Lieu (1966); Mallory (1972); Mapel (1959); Richards and Rogers (1951); Thom and others (1935); Denson, N. M., oral communication (1973); Sandberg, C. A., oral communication (1973).

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
Alluvium----------------	10±	Sand, gravel, silt--------------	Unconsolidated.
Moncrief Conglomerate---	0-2,000	Conglomerate--------------------	
Arikaree Formation------	200±	Sandstone-----------------------	
White River Formation---	200±	Claystone, siltstone, conglomerate.	
Wasatch Formation-------	1,000+	Sandstone, shale, conglomerate--	Many coal beds.
Fort Union Formation----	2,000-4,000	Sandstone, siltstone, shale-----	Do.
Lance Formation Hell Creek Formation.	600-2,200	Sandstone, shale----------------	
Bearpaw Shale-----------	200-865	Shale, sandstone----------------	Some thin bentonite beds.
Judith River Formation--	250-350	Sandstone, shale----------------	Equivalent rocks termed Parkman Sandstone near Montana-Wyoming state line.
Claggett Shale----------	365-650	Shale---------------------------	
Cody Shale--------------	2,600-3,670	Shale, sandstone----------------	Some thin bentonite beds; includes Telegraph Creek Formation north of Montana-Wyoming state line.
Frontier Formation------	260-515	Sandstone, siltstone, shale-----	Some thin bentonite beds.
Mowry Shale-------------	335-525	Shale---------------------------	Several thin bentonite beds.
Thermopolis Shale-------	625	---do---------------------------	Several thin bentonite beds; basal part termed the Skull Creek Shale and Newcastle Sandstone in places south of Montana-Wyoming state line.
Cloverly Formation------	150-240	Sandstone, siltstone, claystone, shale.	Structure contour horizon (plate A-4).
Morrison Formation------	180-230	Shale, claystone, siltstone, sandstone.	
Sundance Formation------	285	Sandstone, shale, limestone-----	Sundance and underlying Gypsum Spring are termed the Ellis Group in places north of Montana-Wyoming state line.
Gypsum Spring Formation-	0-190	Shale, claystone, limestone-----	Some gypsum beds.
Chugwater Formation-----	355-810	Siltstone, shale, sandstone-----	
Goose Egg Formation-----	180-250	Shale, limestone, siltstone-----	Some gypsum beds.
Tensleep Sandstone------	0-420	Sandstone-----------------------	
Amsden Formation--------	200-300	Dolomite, limestone, sandstone, shale.	

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
C. BIGHORN MOUNTAINS, PRYOR MOUNTAINS, AND WESTERN POWDER RIVER BASIN--Continued			
Madison Limestone-------	330-735	Limestone, dolomite------------	
Jefferson Formation-----	0-255	Dolomite-----------------------	
Souris River Formation--	0-16	Limestone----------------------	
Beartooth Butte Formation.	0-140	Dolomite-----------------------	
Bighorn Dolomite--------	0-365	Dolomite, limestone------------	
Gallatin and Gros Ventre Formations.	380-740	Shale, limestone, sandstone-----	
Flathead Sandstone------	215-345	Sandstone----------------------	
D. SOUTHWESTERN POWDER RIVER BASIN, CASPER ARCH, AND SOUTHEASTERN WIND RIVER BASIN Sources of data: Crist and Lowry (1972); Hares (1946); Keefer (1972); Keefer and Van Lieu (1966); Mallory (1972); Olson (1954); Denson, N. M., oral communication (1973); Pipiringos, G. N., oral communication (1973).			
Wind-blown sand---------	0-200	Sand---------------------------	Unconsolidated.
Ogallala Formation------	0-800	Siltstone, sandstone, conglomerate.	Unconsolidated in part.
Arikaree Formation------	0-1,000	Sandstone, limestone, tuff, conglomerate.	
White River Formation---	0-1,465	Sandstone, siltstone, conglomerate.	
Wagon Bed Formation-----	0-1,000	Mudstone, sandstone, conglomerate.	Present in Wind River Basin only: Wind River Formation equivalent in Powder River Basin is Wasatch Formation.
Wind River Formation----	0-7,000	Claystone, shale, sandstone, conglomerate.	
Fort Union Formation----	0-8,000	Sandstone, siltstone, claystone, shale.	Many coal beds in Powder River Basin.
Lance Formation---------	250-5,000	Sandstone, shale, siltstone-----	
Fox Hills Sandstone-----	0-1,000	Sandstone, shale----------------	
Lewis Shale-------------	200-600	Shale, sandstone----------------	
Mesaverde Formation-----	850-1,365	Sandstone, shale----------------	Some thin coal beds in Wind River Basin.
Cody Shale--------------	3,000-5,000	Shale, sandstone----------------	
Frontier Formation------	625-1,000	Sandstone, shale----------------	
Mowry Shale-------------	200-300	Shale--------------------------	Many bentonite beds.
Thermopolis Shale-------	100-200	---do--------------------------	Muddy Sandstone Member at top.
Cloverly Formation------	150-300	Sandstone, claystone, conglomerate.	
Morrison Formation------	150	Sandstone, claystone------------	
Sundance Formation------	225-365	Shale, sandstone, siltstone, limestone.	

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
D. SOUTHWESTERN POWDER RIVER BASIN, CASPER ARCH, AND SOUTHEASTERN WIND RIVER BASIN--Continued			
Jelm Formation	120-395	Siltstone, sandstone	
Red Peak Formation	600-700	Shale, siltstone	
Goose Egg Formation	150-380	Shale, siltstone, limestone	Some gypsum beds.
Tensleep Sandstone	250-280	Sandstone	
Amsden Formation	140-200	Shale, sandstone, limestone	
Madison Limestone	250-325	Limestone	
Gallatin Limestone, Gros Ventre Formation, Flathead Sandstone.	200-800	Sandstone, shale	
E. LARAMIE MOUNTAINS AND SOUTHERN POWDER RIVER BASIN			
Sources of data: Denson and Bottinelly (1949); Denson and Horn (1972); Keefer and Van Lieu (1966); Mallory (1972); Olson (1954); Pipiringos, G. N., oral communication (1973).			
Ogallala Formation	0-400	Claystone, siltstone, sandstone, conglomerate.	
Arikaree Formation	600±	Sandstone, siltstone, limestone	
White River Formation	0-1,100	Siltstone, conglomerate, limestone.	
Wasatch Formation	0-1,800	Sandstone, siltstone, shale	Several coal beds.
Fort Union Formation	2,700-4,300	Sandstone, siltstone, claystone, shale.	Do.
Lance Formation	2,000-3,000	Shale, sandstone	Several thin coal beds in lower part.
Fox Hills Sandstone	500-800	Sandstone, shale	
Lewis Shale	400	Shale, sandstone	
Mesaverde Formation	900	Sandstone, shale	
Cody Shale	3,000-3,600	Shale, sandstone	
Frontier Formation	850-900	---do	
Mowry Shale	200-300	Shale	Several thin bentonite beds.
Thermopolis Shale	75-250	Shale, sandstone	Includes Muddy Sandstone Member.
Cloverly Formation	65-320	Sandstone, claystone, shale, conglomerate.	
Morrison Formation	130-220	Claystone, shale, sandstone, limestone.	
Sundance Formation	220-480	Shale, sandstone, siltstone, limestone.	
Jelm Formation	0-45	Siltstone, sandstone	
Red Peak Formation	580-610	Siltstone, shale, sandstone	Some gypsum beds.
Goose Egg Formation	380-410	Shale, limestone, sandstone	Several gypsum beds.
Casper Formation	525	Sandstone, limestone	Hartville Formation (900-1,225') in southern Niobrara County.

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
E. LARAMIE MOUNTAINS AND SOUTHERN POWDER RIVER BASIN--Continued			
Madison Limestone-------	150-275	Limestone-----------------------	Guernsey Formation (140-260') in southern Niobrara County.
Flathead Sandstone------	0-90	Sandstone, conglomerate---------	
F. BLACK HILLS AND EASTERN POWDER RIVER BASIN			
Sources of data: Dobbin, Kramer, and Horn (1957); Mapel and Pillmore (1963); Robinson, Mapel, and Bergendahl (1964); U.S. Geological Survey and others (1964).			
White River Formation---	0-150	Sandstone, siltstone, claystone-	
Wasatch Formation-------	300±	Sandstone, shale----------------	Numerous coal beds.
Fort Union Formation----	1,200-2,270	---do---------------------------	Do.
Lance Formation, Hell Creek Formation.	500-2,500	---do---------------------------	
Fox Hills Sandstone-----	125-550	Sandstone, shale, siltstone-----	Colgate Sandstone Member at top.
Pierre Shale------------	945-3,100	Shale, claystone----------------	Several thin bentonite beds.
Niobrara Formation------	100-250	Shale---------------------------	Many thin bentonite beds.
Carlile Shale-----------	360-690	---do---------------------------	
Greenhorn Formation-----	70-370	Shale, limestone----------------	
Belle Fourche Shale-----	350-850	Shale---------------------------	
Mowry Shale-------------	150-230	---do---------------------------	Many thin bentonite beds.
Newcastle Sandstone-----	0-100	Sandstone, siltstone, shale, claystone.	Some thin coal and bentonite beds; equivalent to Muddy Sandstone Member of Thermopolis Shale.
Skull Creek Shale-------	160-270	Shale---------------------------	
Fall River Formation----	35-200	Sandstone, shale, siltstone-----	Structure contour horizon (plate A-4).
Lakota Formation--------	45-300	Sandstone, conglomerate, claystone.	Some thin coal beds.
Morrison Formation------	0-220	Claystone, shale, sandstone, limestone.	
Sundance Formation------	175-495	Shale, sandstone, siltstone, limestone.	
Gypsum Spring Formation-	0-125	Claystone, limestone------------	Abundant gypsum.
Spearfish Formation-----	450-825	Shale, siltstone, sandstone-----	Some gypsum beds.
Minnekahta Limestone----	30-50	Limestone-----------------------	
Opeche Formation--------	50-100	Sandstone, siltstone, shale-----	
Minnelusa Formation-----	650-1,000	Sandstone, limestone, dolomite--	Some gypsum and anhydrite.
Pahasapa Limestone------	500-600	Limestone-----------------------	
Englewood Limestone-----	50±	---do---------------------------	
Whitewood Dolomite------	50±	Dolomite------------------------	

Geologic unit	Thickness (feet)	Principal rock type(s)	Remarks
F. BLACK HILLS AND EASTERN POWDER RIVER BASIN--Continued			
Winnepeg Formation------	50-100	Sandstone, shale, siltstone-----	
Deadwood Formation------	300-400	Sandstone, limestone, shale, siltstone.	
G. SOUTHEASTERN MONTANA AND ADJACENT AREAS IN NORTH AND SOUTH DAKOTA			
Sources of data: Denson and Gill (1965); U.S. Geological Survey and others (1973).			
Glacial deposits--------	0-600	Sand, gravel, silt--------------	Unconsolidated.
Flaxville Formation-----	20-200	Sandstone, conglomerate, tuff, mudstone.	Largely unconsolidated.
Arikaree Formation------	200-360	Sandstone, limestone, shale, conglomerate.	
White River Formation---	250±	Sandstone, claystone, shale, siltstone, conglomerate.	Some bentonite beds.
Golden Valley Formation-	0-175	Sandstone, siltstone, claystone-	Some thin beds of lignite.
Fort Union Formation----	1,250-2,300	Sandstone, shale, siltstone-----	Many lignite beds.
Hell Creek Formation----	400-575	Claystone, sandstone------------	Some thin lignite beds.
Fox Hills Sandstone-----	25-300	Sandstone, shale----------------	
Pierre Shale------------	1,700-2,500	Claystone, shale----------------	Some thin bentonite beds.

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APPENDIX B

MAJOR STRATIGRAPHIC AND TIME DIVISIONS

Subdivisions in Use by the U. S. Geological Survey			Age estimates commonly used for boundaries (in million years)[1]	
Era or Erathem	System or Period	Series or Epoch	(A)	(B)
Cenozoic	Quaternary	Holocene		
		Pleistocene	1.5-2	1.8
	Tertiary	Pliocene	ca. 7	5.0
		Miocene	26	22.5
		Oligocene	37-38	37.5
		Eocene	53-54	53.5
		Paleocene	65	65
Mesozoic	Cretaceous[3]	Upper (Late) Lower (Early)	136	
	Jurassic	Upper (Late) Middle (Middle) Lower (Early)	190-195	
	Triassic	Upper (Late) Middle (Middle) Lower (Early)	225	
Paleozoic	Permian[3]	Upper (Late) Lower (Early)	280	
	Pennsylvanian[3]	Upper (Late) Middle (Middle) Lower (Early)	320[2]	
	Mississippian[3]	Upper (Late) Lower (Early)	345	
	Devonian	Upper (Late) Middle (Middle) Lower (Early)	395	
	Silurian[3]	Upper (Late) Middle (Middle) Lower (Early)	430-440	
	Ordovician[3]	Upper (Late) Middle (Middle) Lower (Early)	ca. 500	
	Cambrian[3]	Upper (Late) Middle (Middle) Lower (Early)	570	
Precambrian	Time subdivisions of the Precambrian: Precambrian Z--base of Cambrian to 800 m.y. Precambrian Y--800 m.y. to 1,600 m.y. Precambrian X--1,600 m.y. to 2,500 m.y. Precambrian W--older than 2,500 m.y.			

GEOLOGIC NAMES COMMITTEE, U. S. GEOLOGICAL SURVEY, 1972

[1] Estimates for ages of time boundaries are under continuous study and subject to refinement and controversy. Two scales are given for comparison:

(A) Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, suppl., p. 260-262.

(B) Berggren, W. A., 1972, A Cenozoic time-scale--some implications for regional geology and paleobiogeography: Lethaia, v. 5, no. 2, p. 195-215.

In addition to these, a useful time scale for North American mammalian stages is given by:

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Amer. Jour. Sci., v. 262, p. 145-198.

[2] From Table 1: Correlation chart for the Carboniferous of north-west Europe, Russia, and North America: Geol. Soc. London, 1964[1], p. 222.

[3] Includes provincial series accepted for use in U. S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms--early, middle, and late--may be used for the eras, for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms--lower, middle, and upper--may be used where there is no formal subdivision of an era, system, or series.

PROVINCIAL SERIES ACCEPTED FOR USE IN U.S. GEOLOGICAL SURVEY REPORTS

Series	Age	Region
Gulfian	Late Cretaceous	Texas, Louisiana, Oklahoma, Arkansas, Mississippi, and Alabama.
Comanchean	Early and Late Cretaceous	
Coahuilan	Early Cretaceous	Texas, Louisiana, Arkansas, Mississippi, and Alabama.
Ochoan	Late Permian	Texas and New Mexico.
Guadalupian	Early and Late Permian	Do.
Leonardian	Early Permian	Do.
Wolfcampian	Early Permian	Do.
Virgilian	Late Pennsylvanian	Arkansas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa.
Missourian	do	
Des Moinesian	Middle Pennsylvanian	
Atokan	do	
Morrowan	Early Pennsylvanian	
Chesterian	Late Mississippian	Indiana, Kentucky, Tennessee, Illinois, Iowa, and Missouri.
Meramecian	do	
Osagean	Early Mississippian	
Kinderhookian	do	
Cayugan	Late Silurian	New York and Michigan.
Niagaran	Middle Silurian	Do.
Alexandrian	Early Silurian	Missouri, Illinois, and Michigan.
Cincinnatian	Late Ordovician	Ohio, Indiana, Kentucky, Tennessee, Michigan, Wisconsin, and Iowa.
Mohawkian	Middle Ordovician	New York, Michigan, Wisconsin, and Iowa.
St. Croixan	Late Cambrian	Iowa, Minnesota, Wisconsin, and Michigan.

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APPENDIX C

SLOPE MAPS

Maps showing detailed slope characteristics were prepared for five selected 7 1/2-minute quadrangles at widely scattered localities in the Northern Great Plains region. Such information, derived directly from topographic contour maps, is important for land use planning and for the construction of engineering works where extensive modification of the natural landscape is involved. In particular, slope maps contain valuable data for: selecting transportation, utility line, and communication routes; siting of mines and related facilities; controlling drainage and erosion; and determining reclamation potential of lands subject to surface mining.

Slope inclinations are commonly given in percent, which expresses the relation between the change in elevation along a given slope and the horizontal distance in which this change takes place. A 20 percent slope, for example, is one along which there is a one unit rise (or drop) in elevation for every five units of horizontal distance (a ratio of 5 to 1). The designation of various slope categories is flexible, and can be designed to suit the particular needs of the study involved. For purposes of the present study, slopes are classified as follows:

Percent slope	Slope angle	Topographic character
0 - 8%	0 - 4° 34'	Flat to gently undulating
8 - 20%	4° 34'- 11° 19'	Undulating to rolling
20 - 35%	11° 19'- 19° 17'	Rolling to strongly rolling
> 35%	> 19° 17'	Steep

The initial cut-off at 8 percent marks the point at which slope inclination becomes an increasingly important factor in the planning and engineering of construction works and the control of erosion. The next cut-off, at 20 percent, indicates a 5 to 1 slope ratio which represents one of the more common slope categories with respect to surface mining. For example, regulations governing the reclamation of surface-mined lands may require, in some cases, the reshaping of spoils so as to eliminate all slopes that exceed 20 percent. The final cut-off at 35 percent was selected because it delineates slope inclinations of about 20 degrees, beyond which surface mining generally involves some form of contour mining. A 35 percent slope also approximates a 3 to 1 slope ratio, which is likewise one of the more common slope categories especially in regard to reclamation practices; several states require that all high walls be graded to slopes that have ratios less than 3 to 1 upon completion of mining.

The five quadrangles--two in Wyoming, two in Montana, and one in North Dakota--were selected as being representative of the regions in which they are located. Portions of each are underlain by strippable coal deposits, though the latter have not been plotted. The maps exhibit a variety of landscapes, ranging from virtually flat terrain (Reno Reservoir, Wyoming) to highly dissected badlands (Cook Creek Reservoir, Montana). The proportion of "dark-colored" areas on each map is a direct measure of the difficulty that might be expected in restoring surface-mined land to the approximate original contour, thereby blending it in with the surrounding, undisturbed terrain. It is interesting to note in this regard that features associated with surface mining in both the Beulah (North Dakota) and Colstrip East (Montana) quadrangles locally form some of the steepest topography within their respective areas.

The slope maps were prepared by personnel of the Rocky Mountain Mapping Center, Topographic Division, U.S. Geological Survey, Denver, Colorado. Attention should be given to the note at the bottom of each map sheet, which describes the techniques used in measuring slope inclinations and explains that false slope information may result under certain local terrain conditions.

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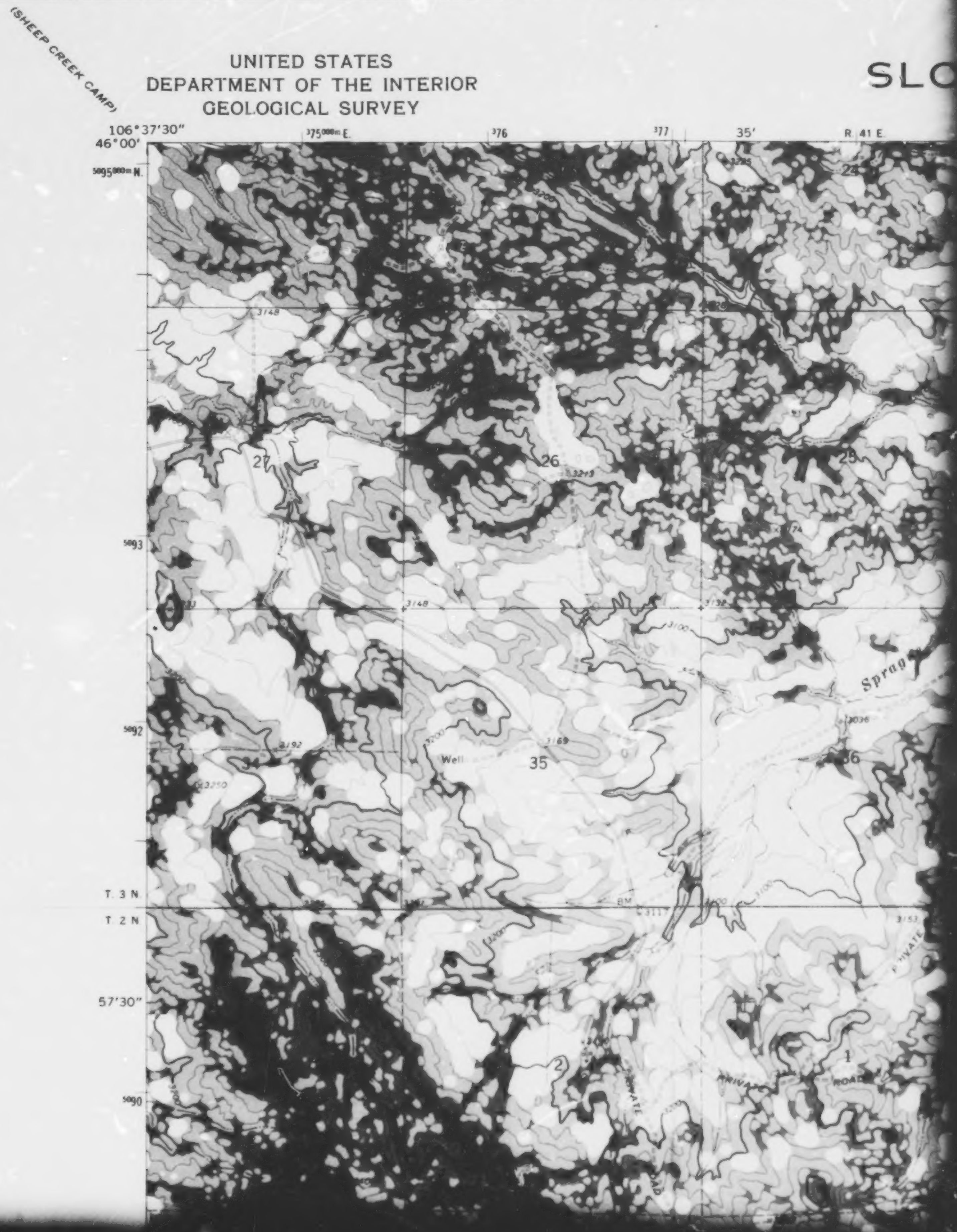
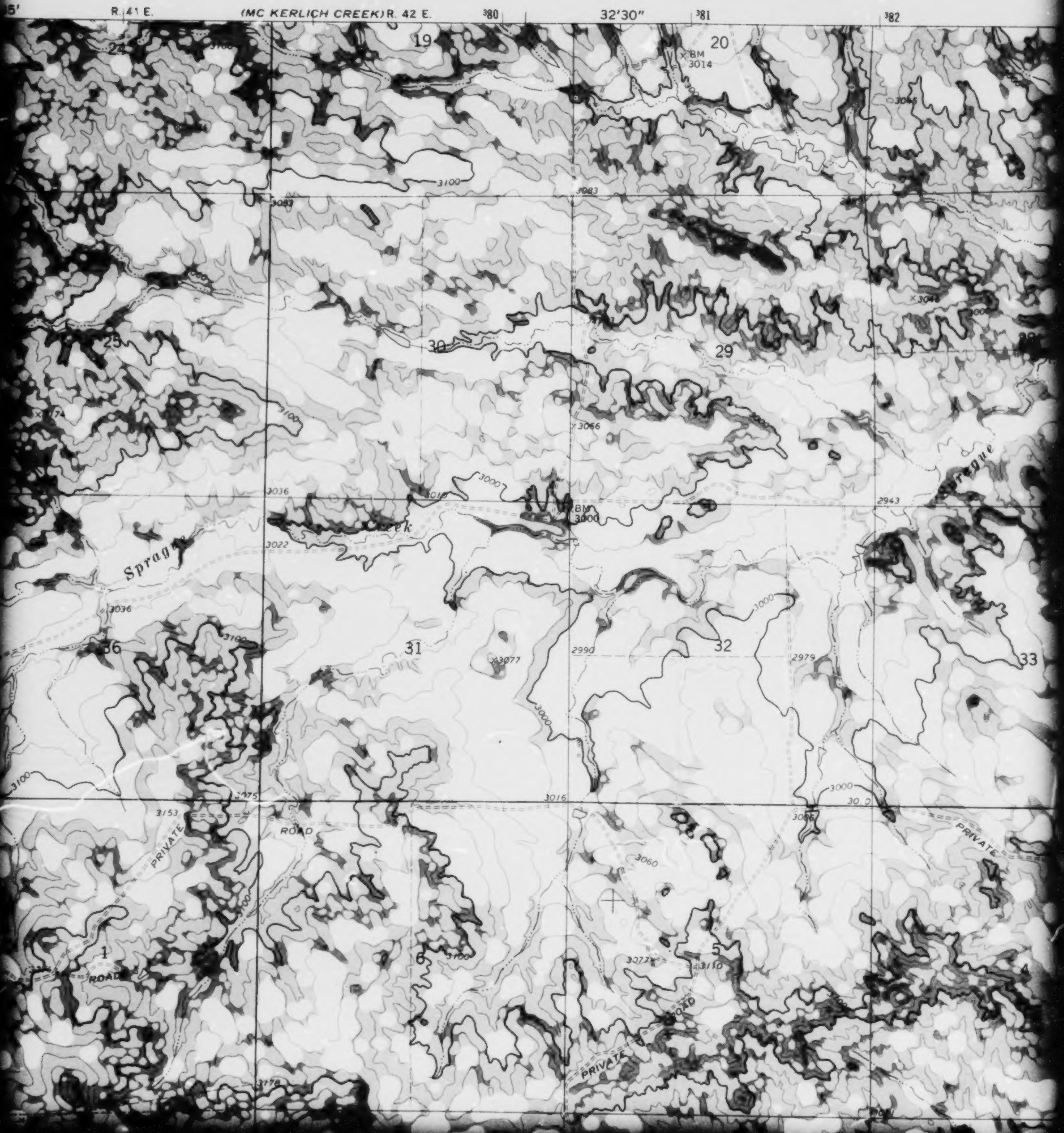
SLO

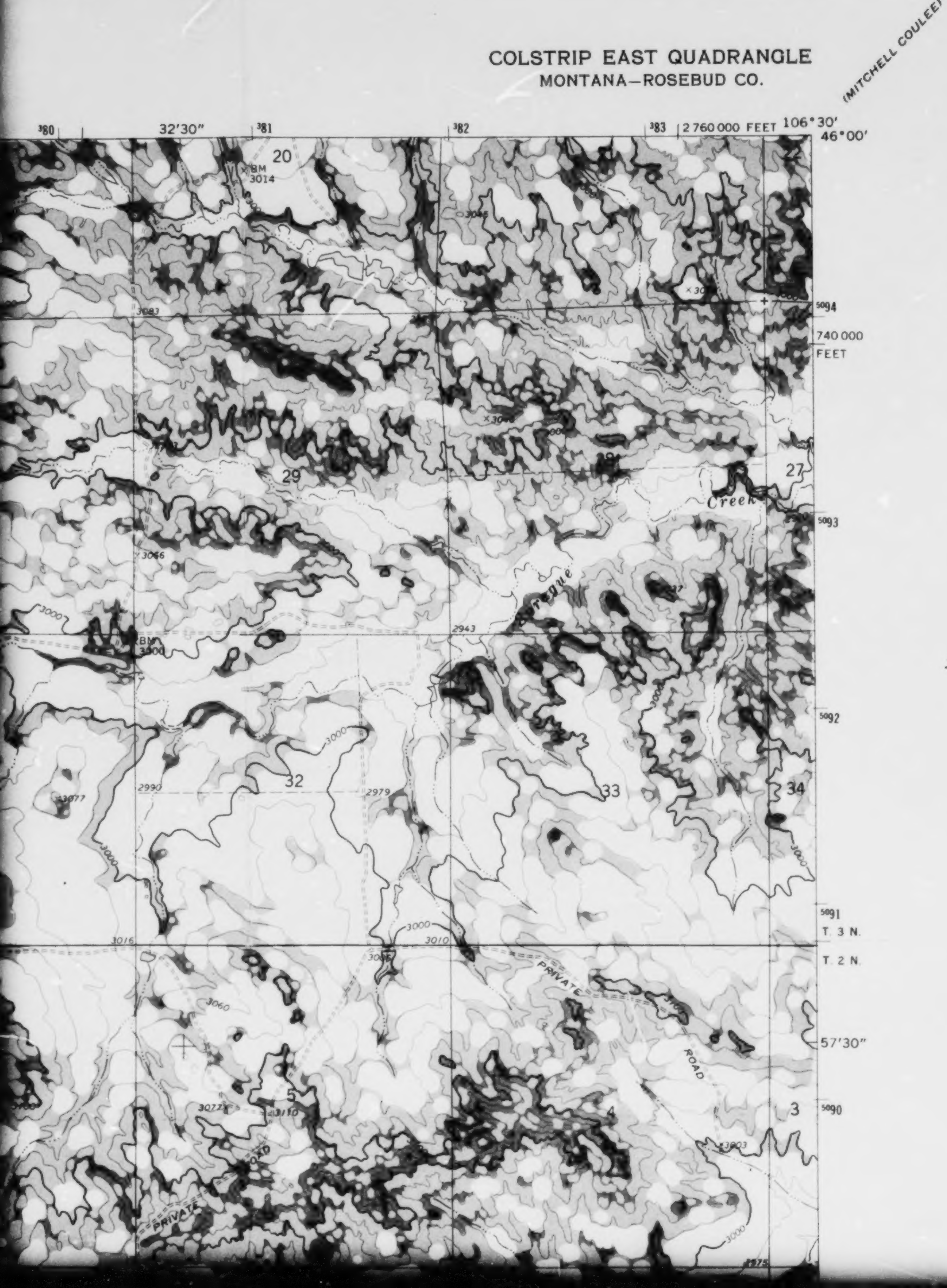


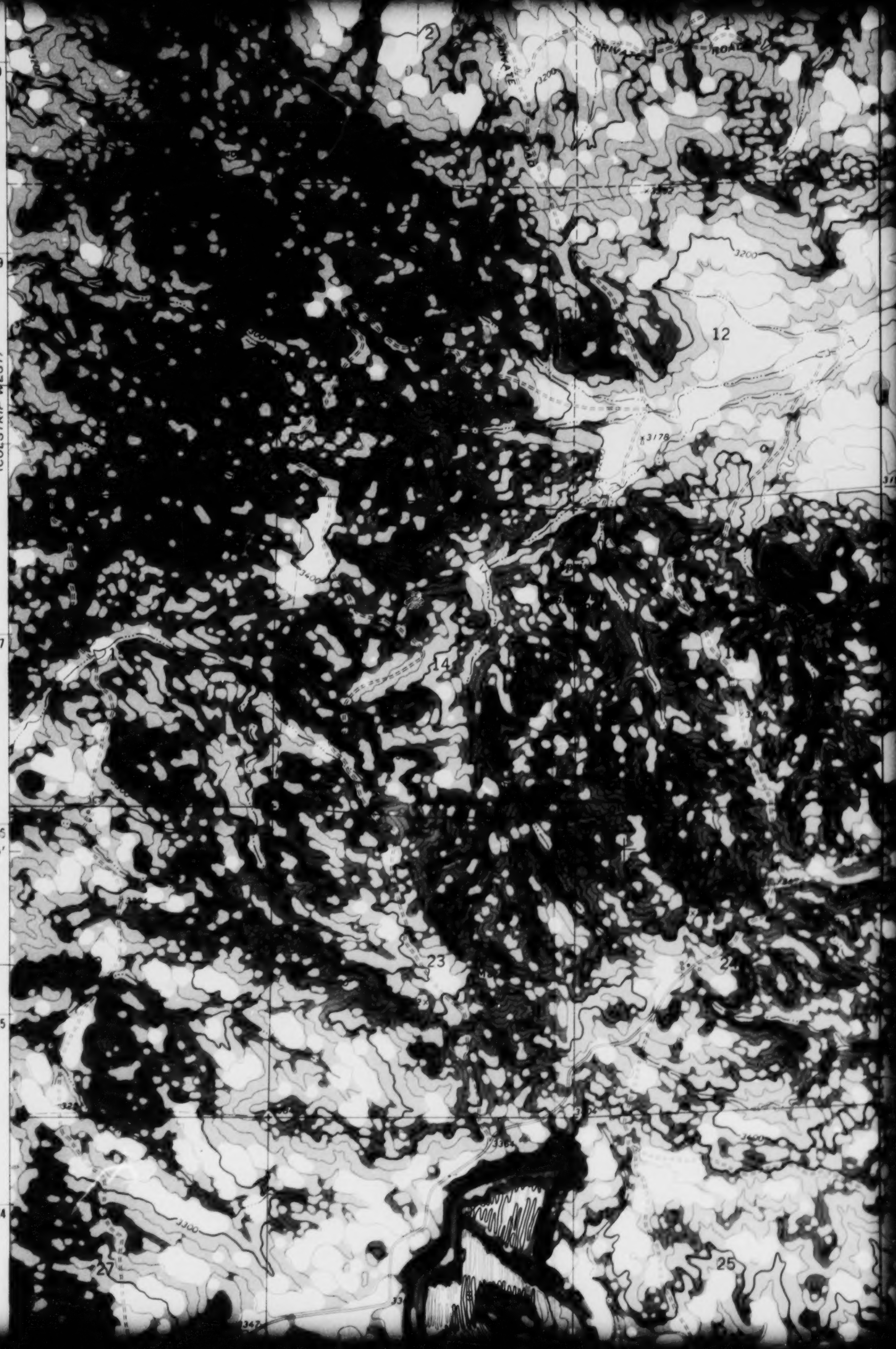
SLOPE MAP

COLSTRIP EA
MONTANA



COLSTRIP EAST QUADRANGLE
MONTANA–ROSEBUD CO.

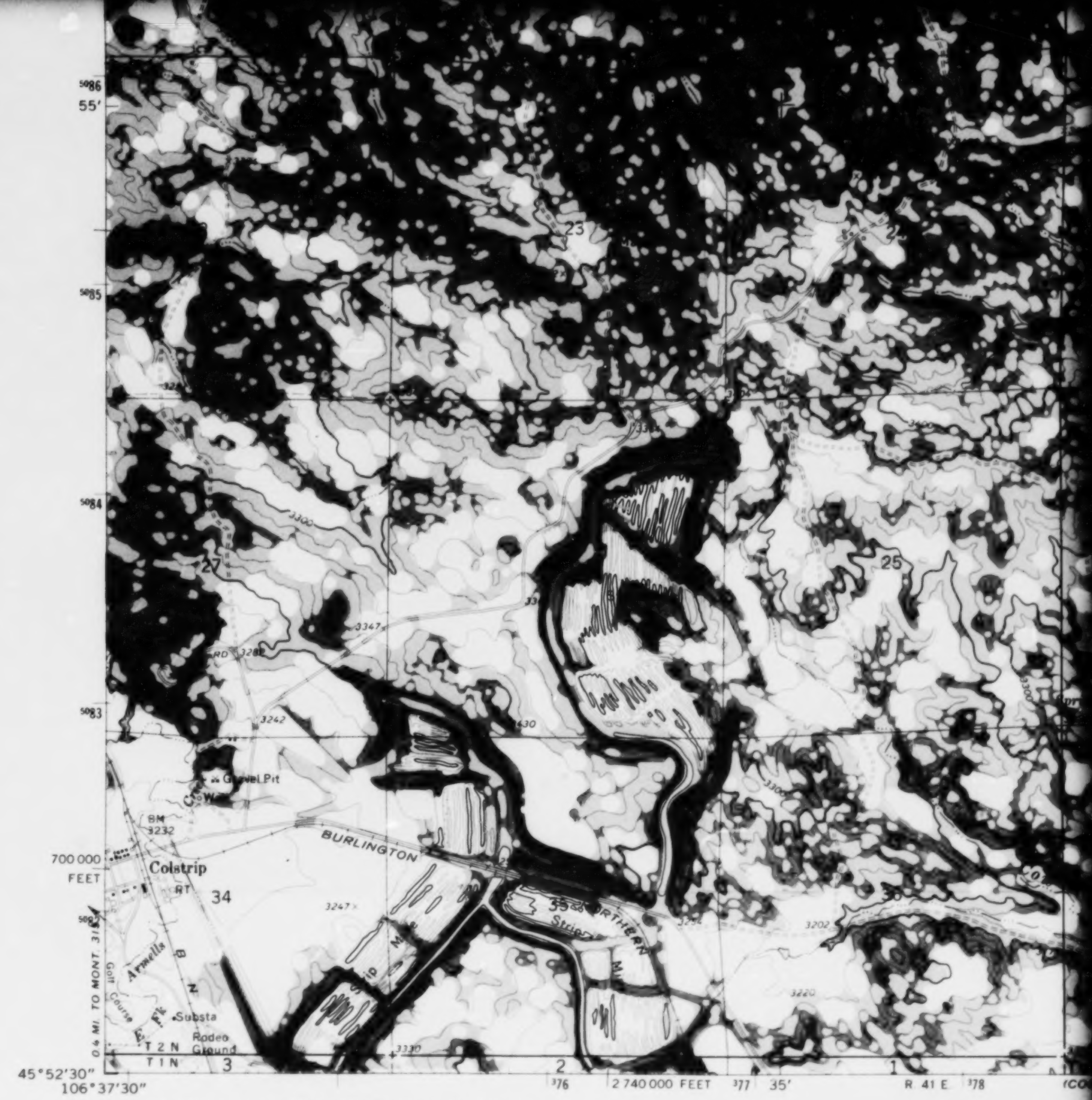




(COLSTRIP WEST)
PRIVATE ROAD
5090
5089
5087
55′
5085
5084
3200
3178
3400
3300
1
2
12
14
23
24
25
27

PRIVATE
Spring
Creek
Creek
12
7
8
25
30
29
3200
3100
3040
3027
3192
3170
3400
3433
3200

57'30"
ROAD
3
5090
3072
3110
PRIVATE ROAD
3003
3000
2975
Creek
5089
Spring
3100
3040
3027
8
9
10
(HAMMOND DRAW NW)
3087
3100
3104
5087
3351
5086
3433
3400
55'
3111
31
5085
Creek
3182
3100
5084

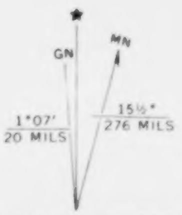


Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1971

Projection and 10,000-foot grid ticks: Montana coordinate system, south zone (Lambert conformal conic)
1000-meter Universal Transverse Mercator grid ticks, zone 13. 1927 North American datum



UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCA

CONTOUR

DATUM IS

Note: The slope zones on this map are
photomechanical process which transla
of slope. Proximity of the same contour
false slope information at small tops and
narrow drains and incised stream chann

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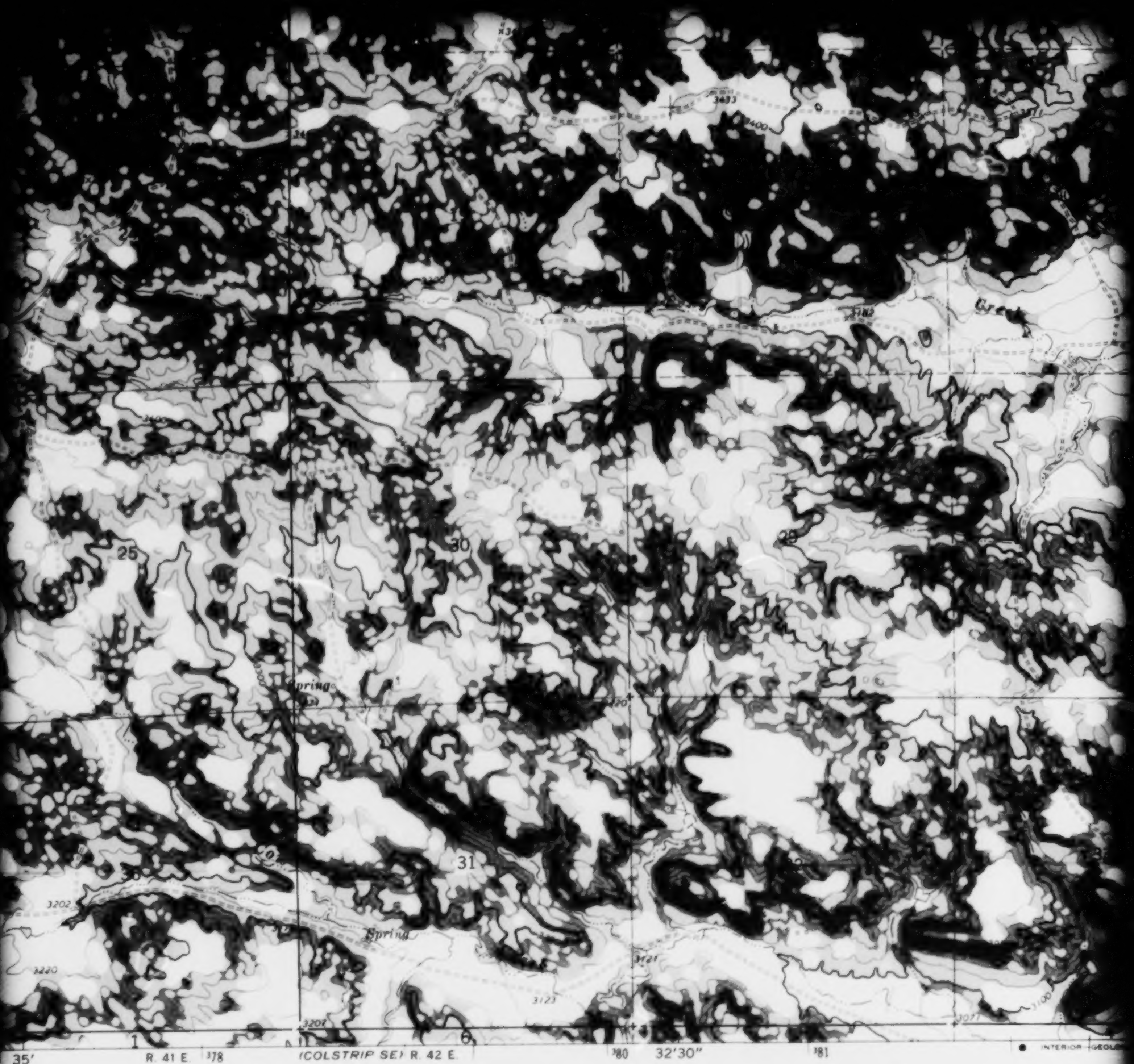

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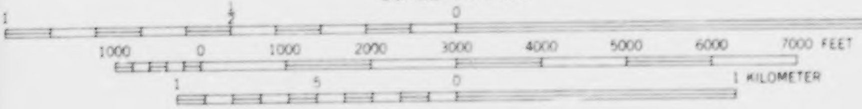
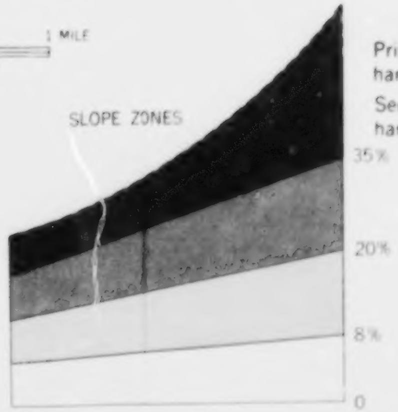


CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Note: The slope zones on this map are unedited. They were generated manually and by a photomechanical process which translates distance between adjacent contours into percentage of slope. Proximity of the same contour or absence of adjacent contours may have produced false slope information at small tops and depressions, on cuts and fills, along ridge crests, narrow drains and incised stream channels, along shores of open water, and at edges of the map

SLOPE ZONES



ROAD CLAS

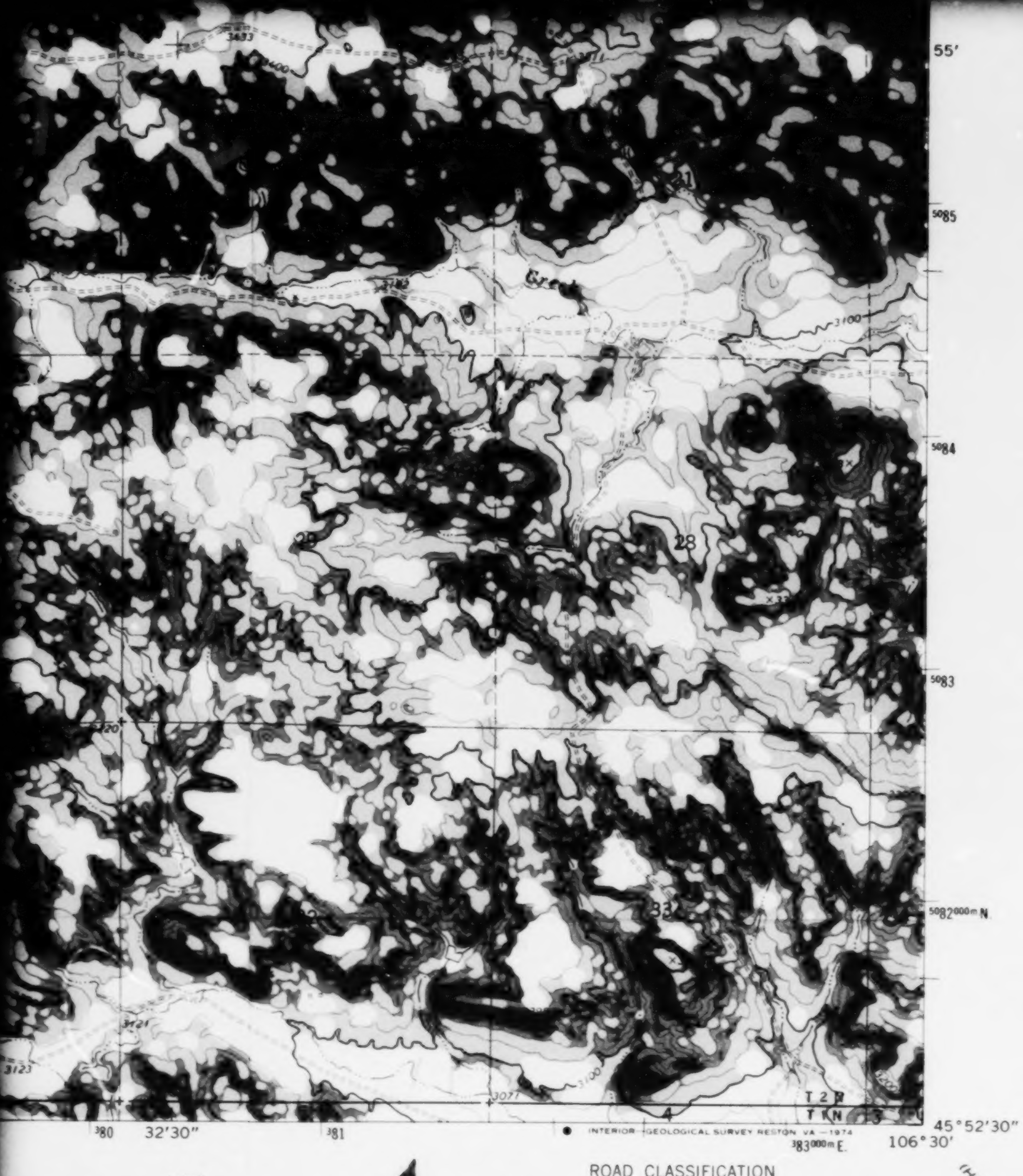
Primary highway, hard surface

Secondary highway, hard surface

Interstate Route

U

COLS



INTERIOR—GEOLOGICAL SURVEY RESTON VA—1974

1 MILE
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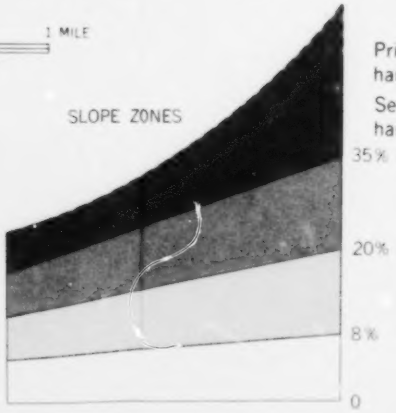
1 KILOMETER

(HAMMOND DRAW SW)



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ROAD CLASSIFICATION

Primary highway, hard surface	Light-duty road, hard or improved surface
Secondary highway, hard surface	Unimproved road

Interstate Route U. S. Route State Route

COLSTRIP EAST, MONT.

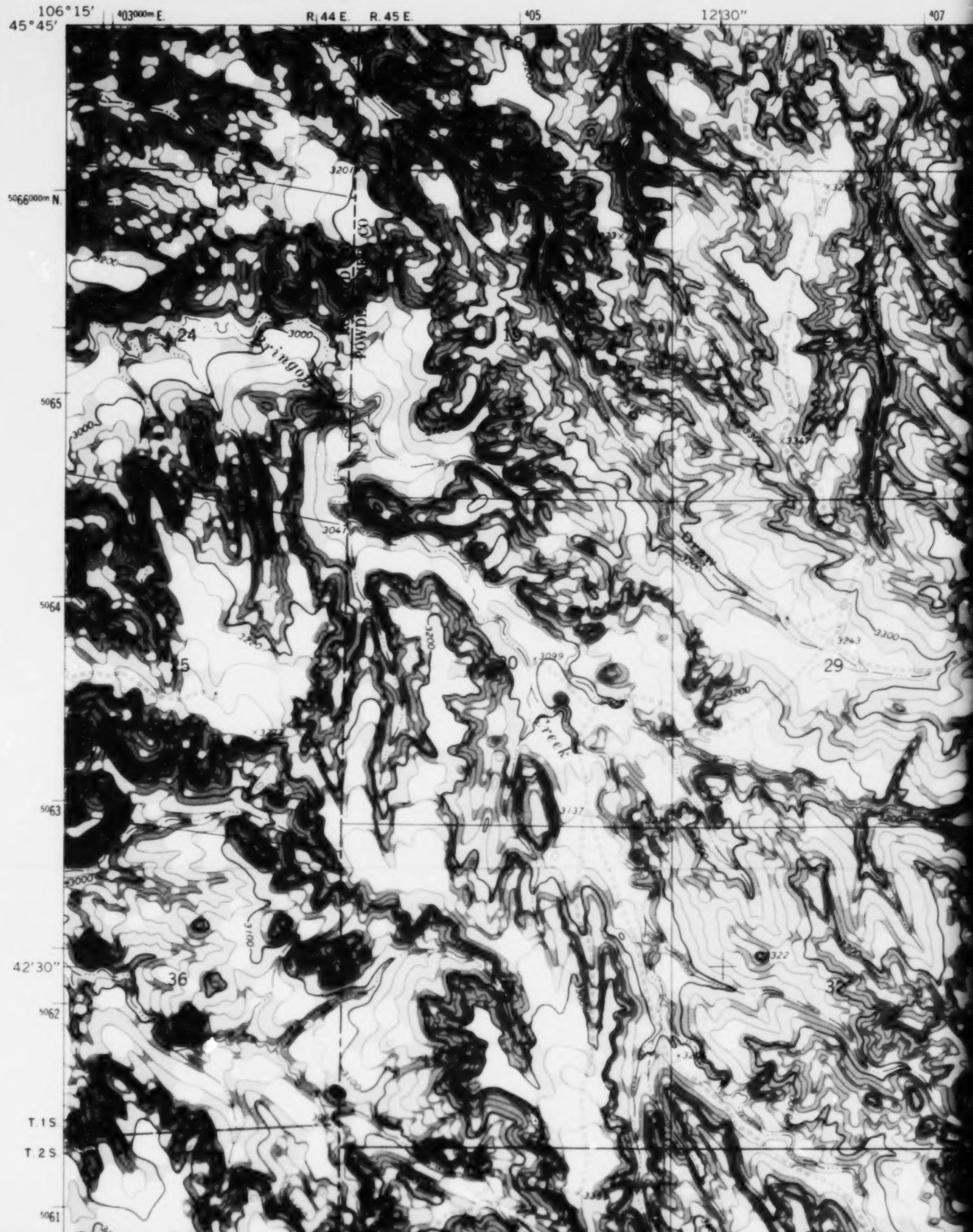
N4552.5—W10630/7.5

1971

AMS 4675 I NE—SERIES V894

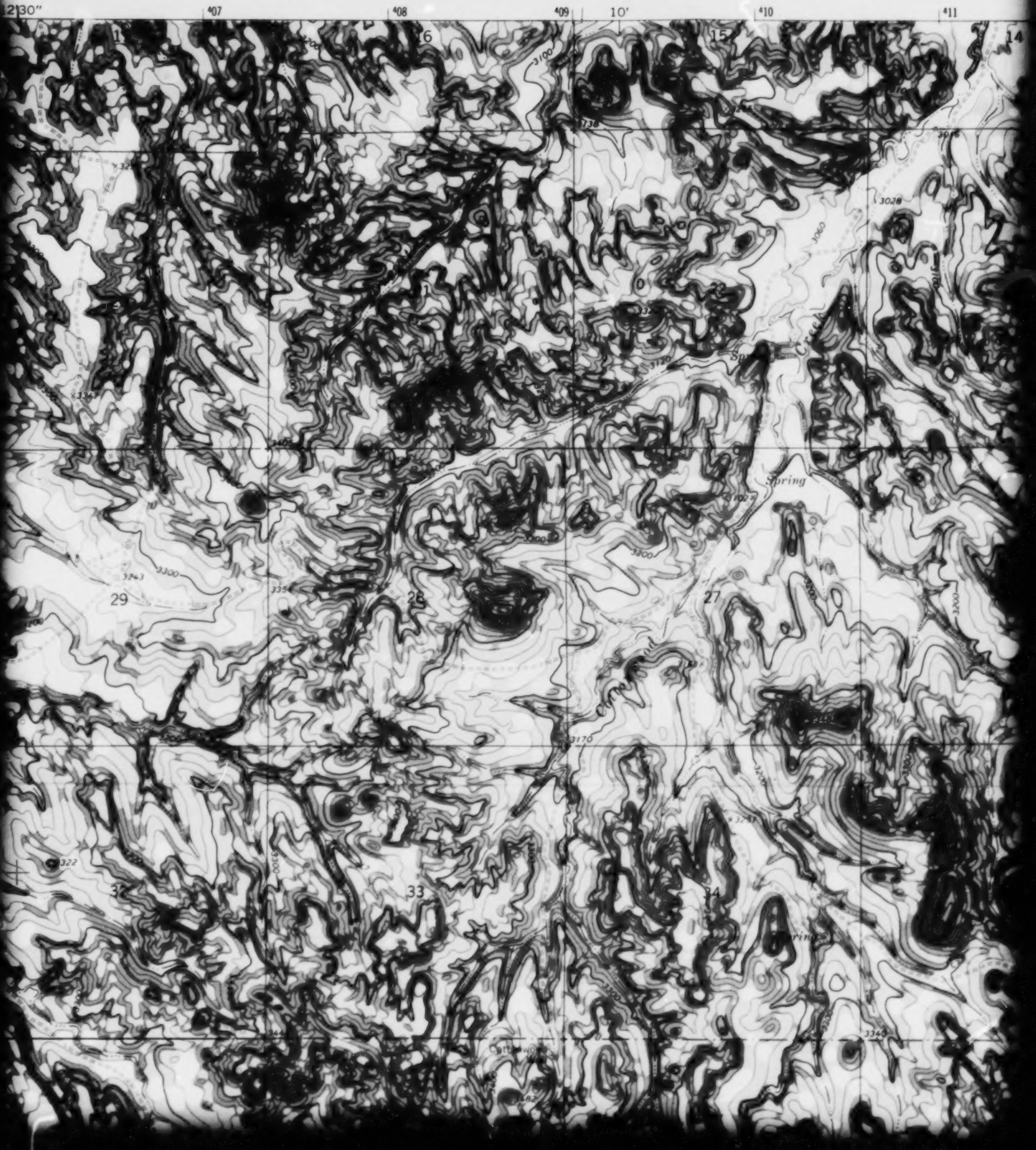
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SL

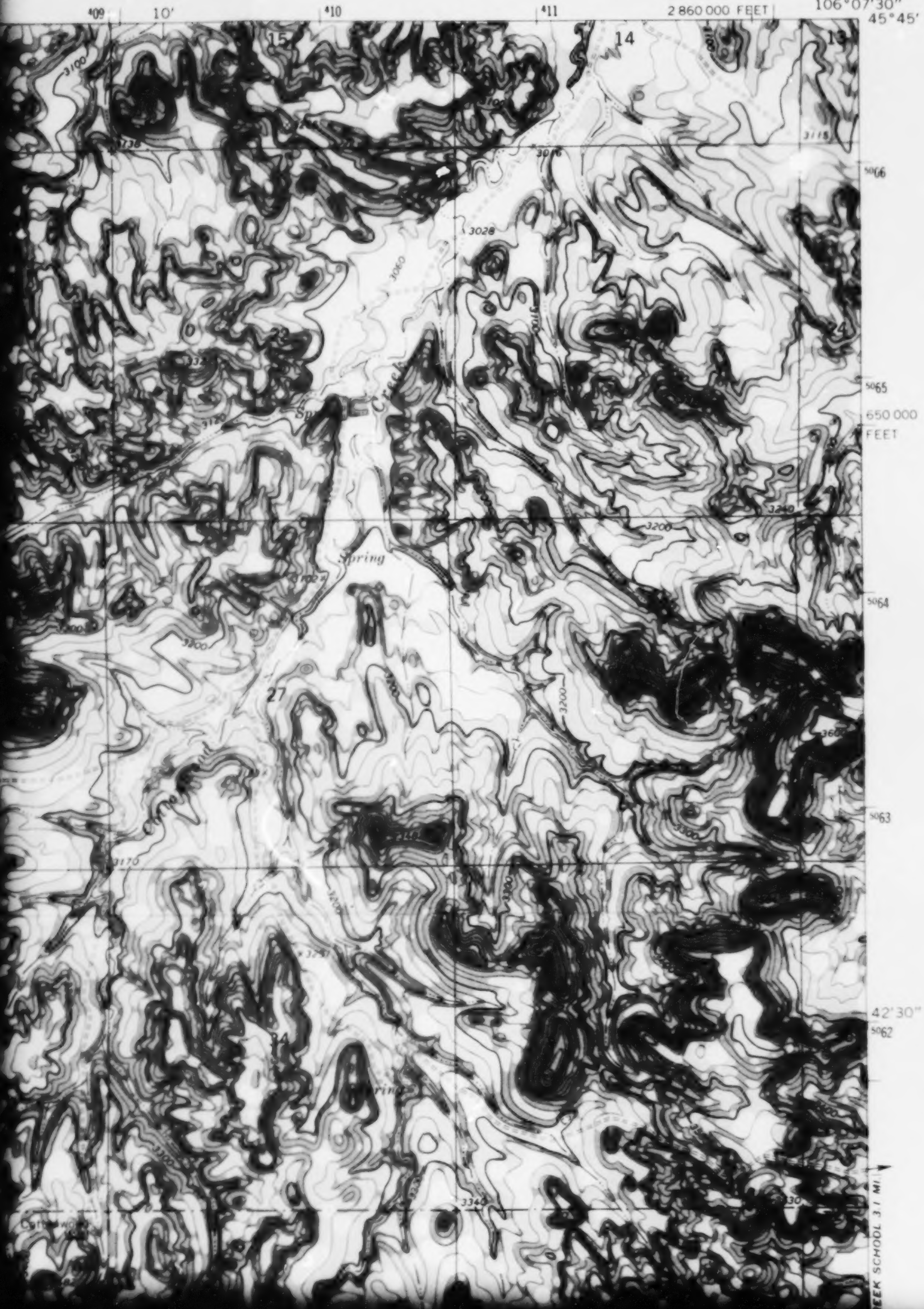


SLOPE MAP

COOK CREEK RESER
MONTA



COOK CREEK RESERVOIR QUADRANGLE
MONTANA



42'30"
36
5062
T.1S.
T.2S.
5061
(ASHLAND NE)
5059
5058
40'
5057
5056
3100
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3198
3263
3300
3107
3320
3266
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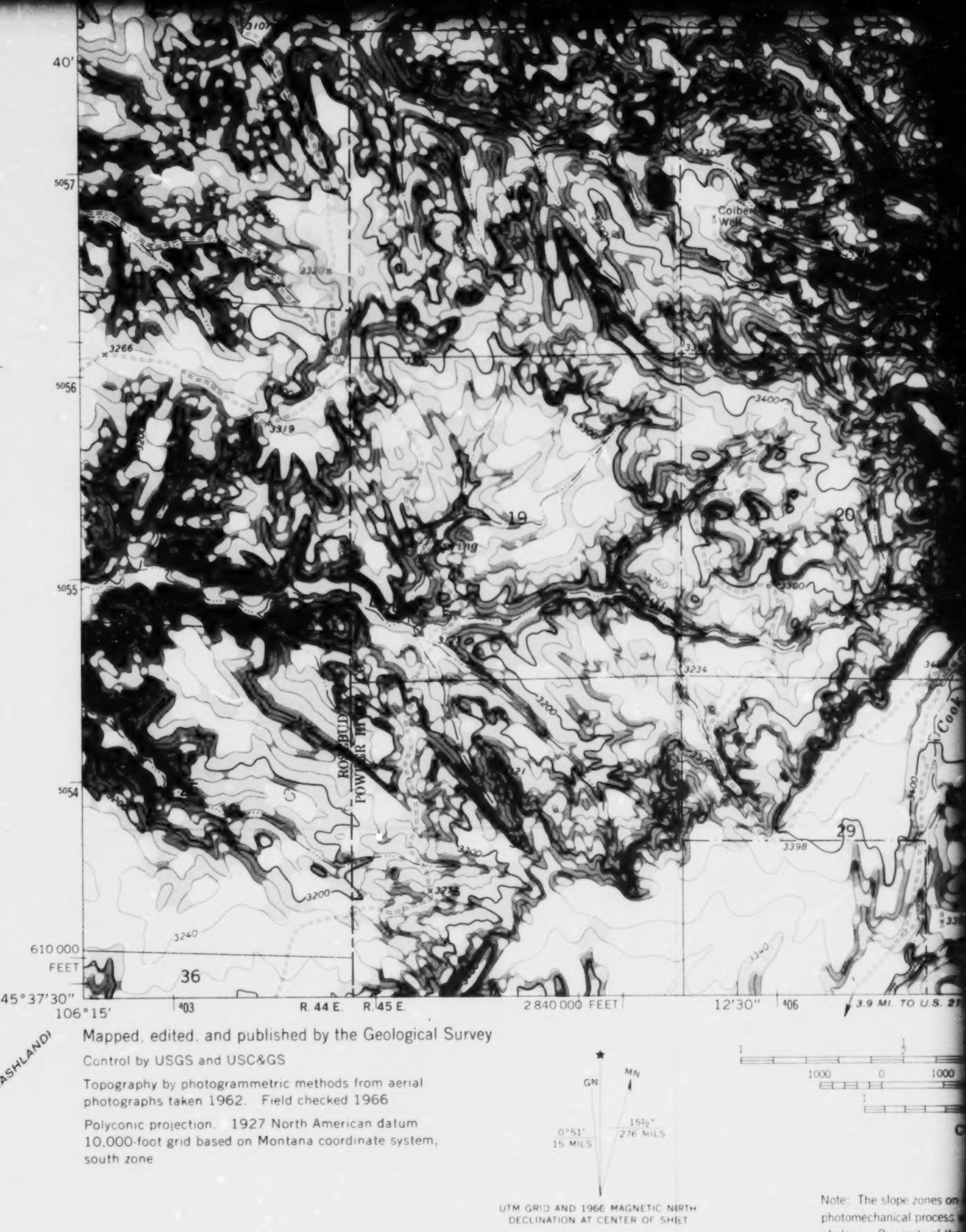
3400
Colbert
Colbert Well

33
4
3700
3400
3300
3600
Colbert
Well

42'30"
5062
BEAVER CREEK SCHOOL 3.1 MI.
(BEAVER CREEK SCHOOL)
5059
Spring
5058
40'
5057
5056



(ASHLAND)

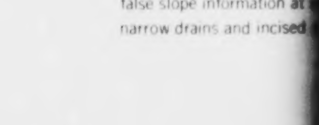
Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1962. Field checked 1966

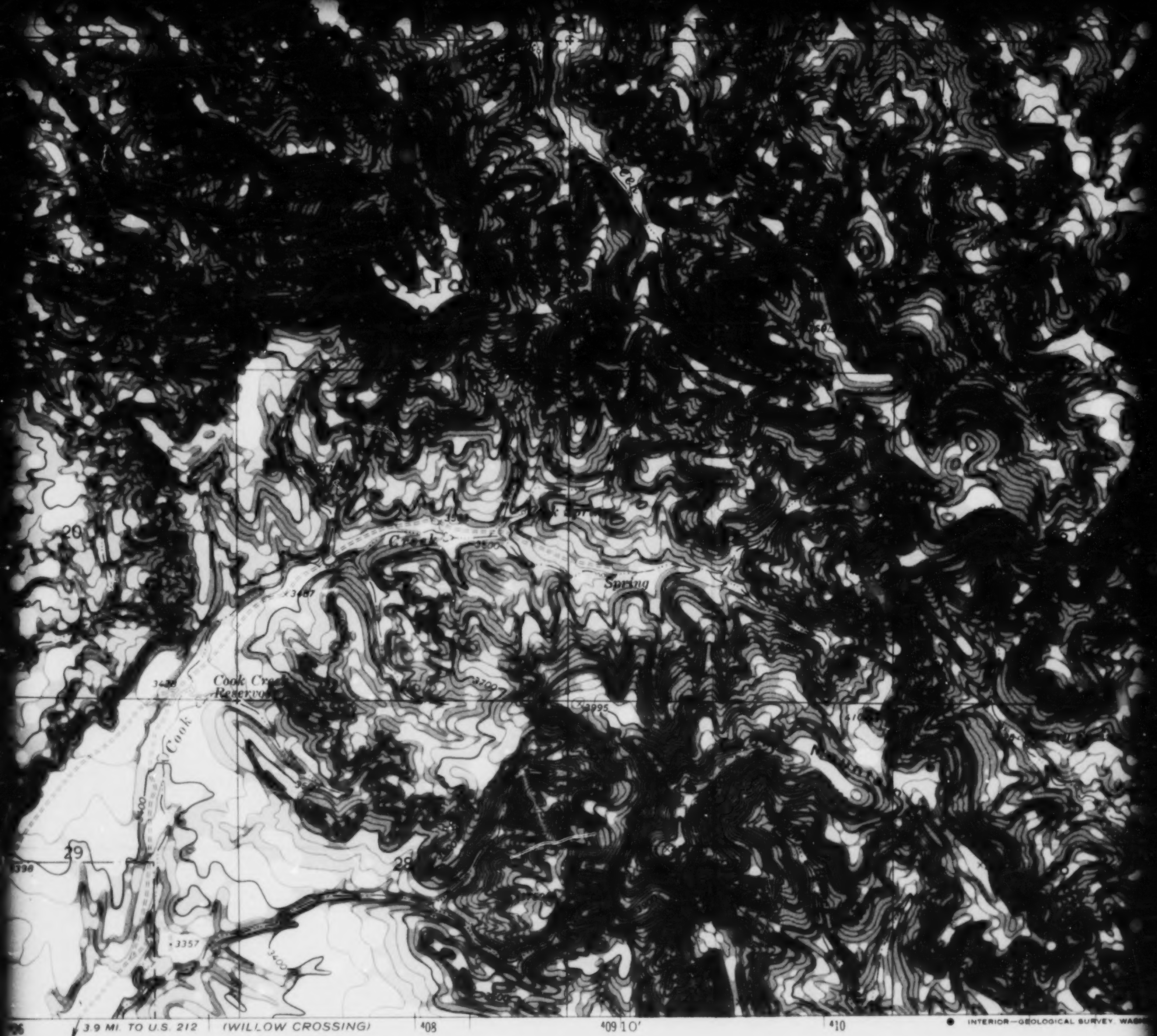
Polyconic projection. 1927 North American datum
10,000-foot grid based on Montana coordinate system, south zone

UTM GRID AND 1966 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET



Note: The slope zones on
photomechanical process
of slope. Proximity of the
false slope information at
narrow drains and incised

☆ GPO 781-902



SCALE 1:24 000

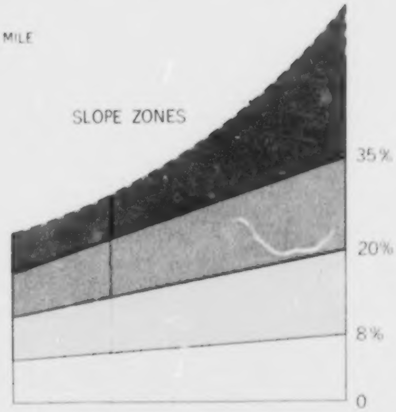
½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Note: The slope zones on this map are unedited. They were generated manually and by a photomechanical process which translates distance between adjacent contours into percentage of slope. Proximity of the same contour or absence of adjacent contours may have produced false slope information at small tops and depressions, on cuts and fills, along ridge crests, narrow drains and incised stream channels, along shores of open water, and at edges of the map



RO
Unim

COOK CREEK RESE
N4537.5—W106

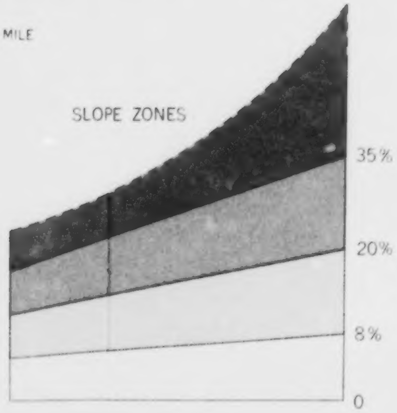
1966

(COLEMAN DRAW)

1 MILE

000 FEET

ETER



ROAD CLASSIFICATION

Unimproved dirt - - - - - - -

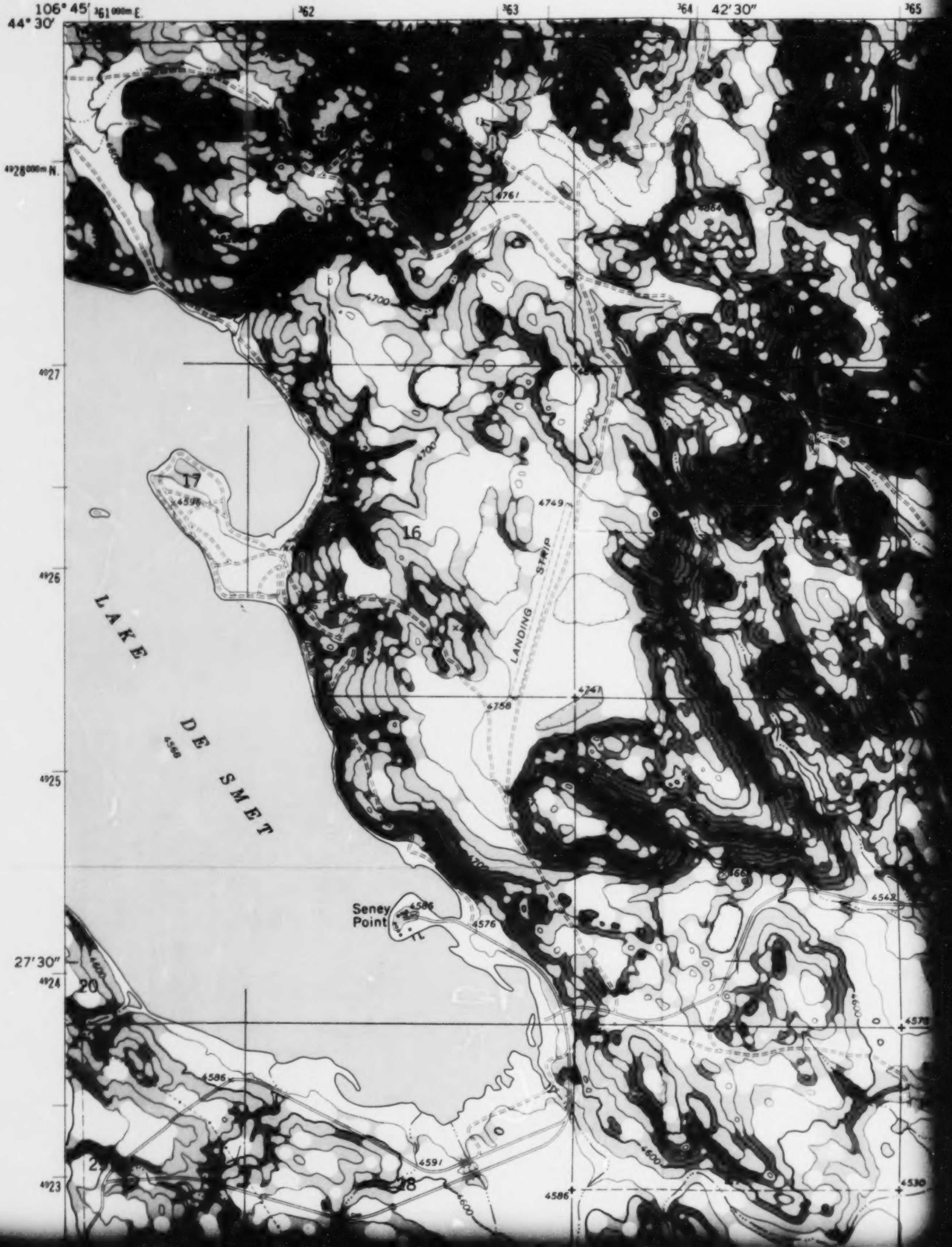
COOK CREEK RESERVOIR, MONT.

N4537.5—W10607.5/7.5

1966

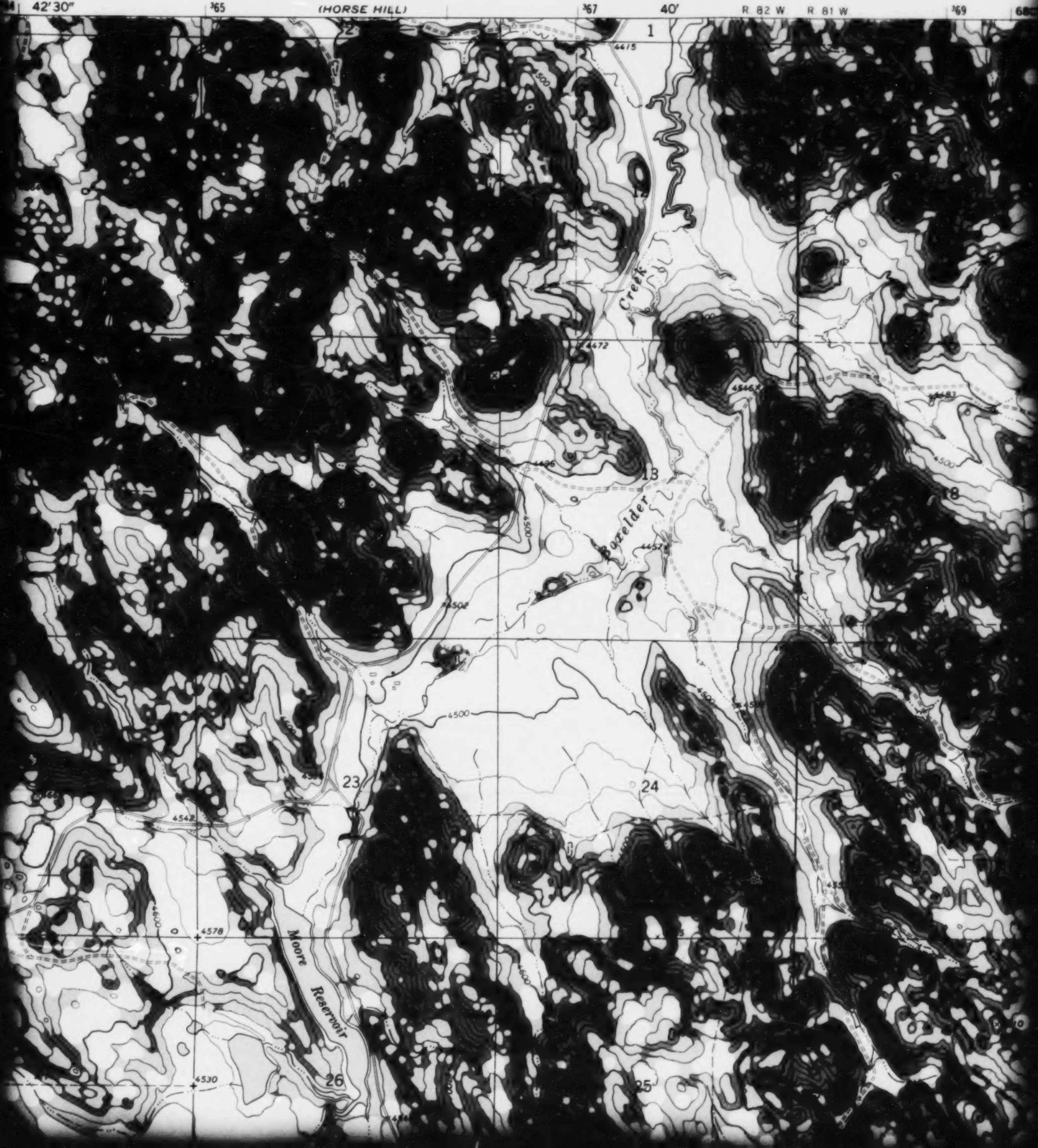
(BANNER)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



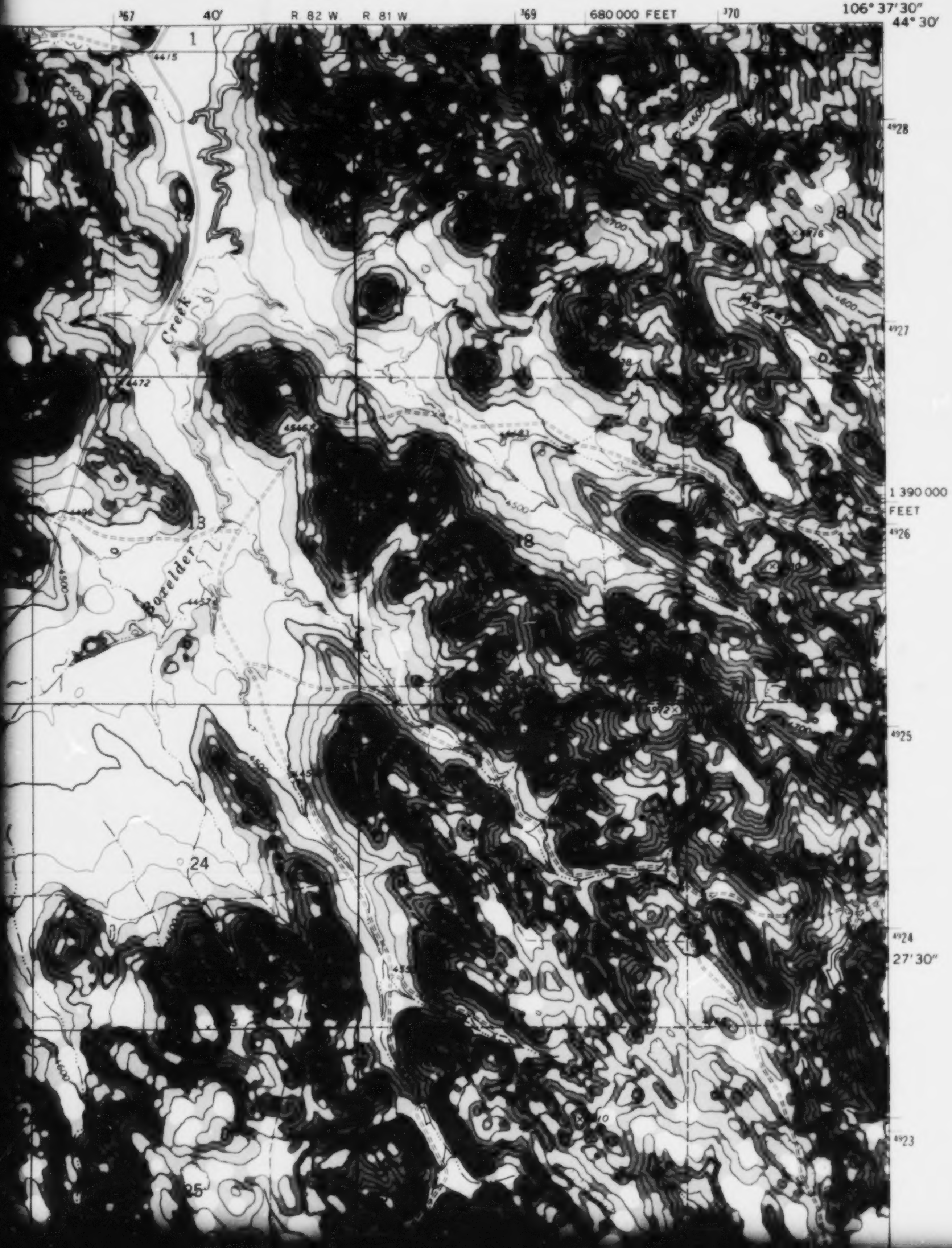
SLOPE MAP

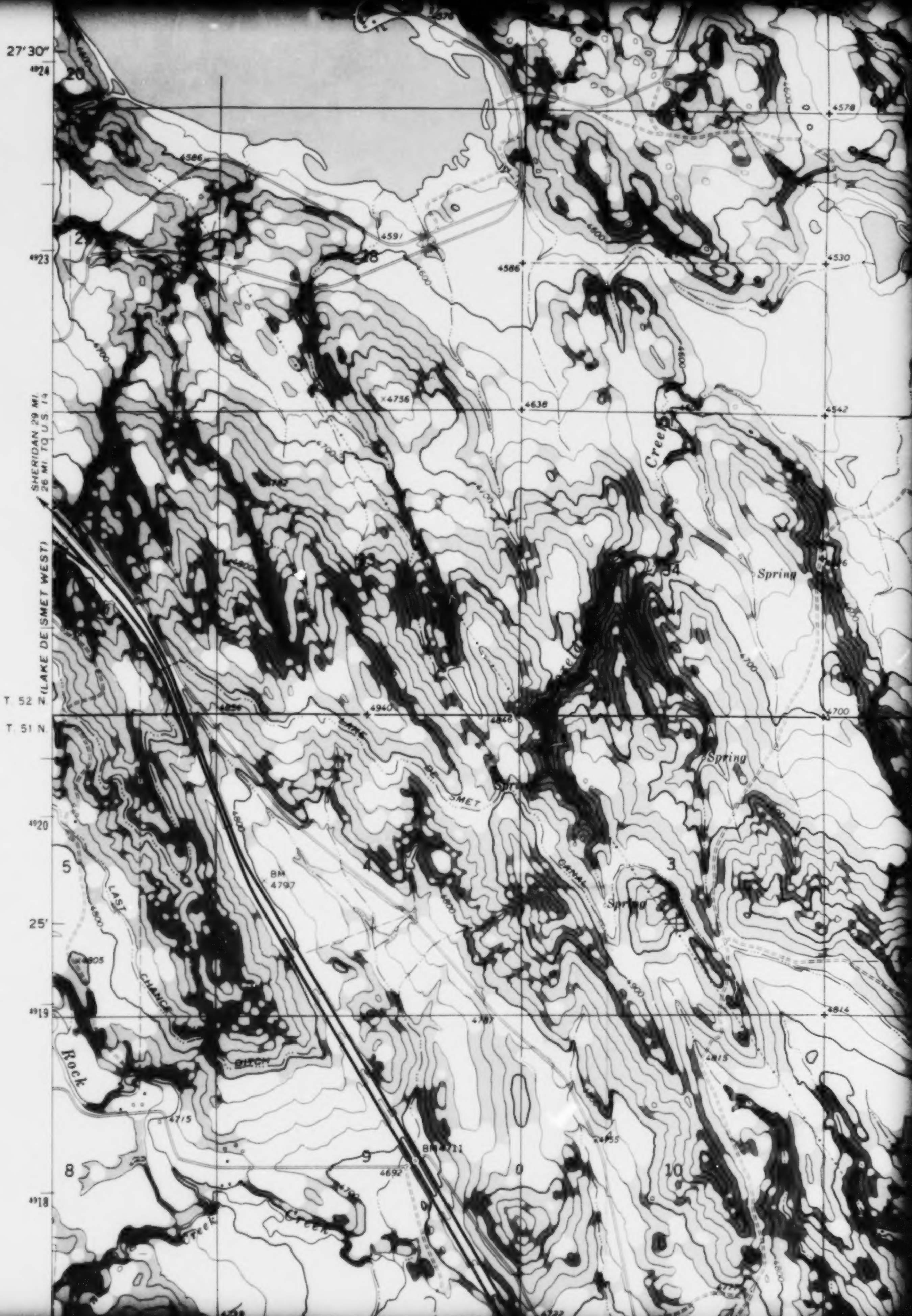
LAKE DE S
WYO

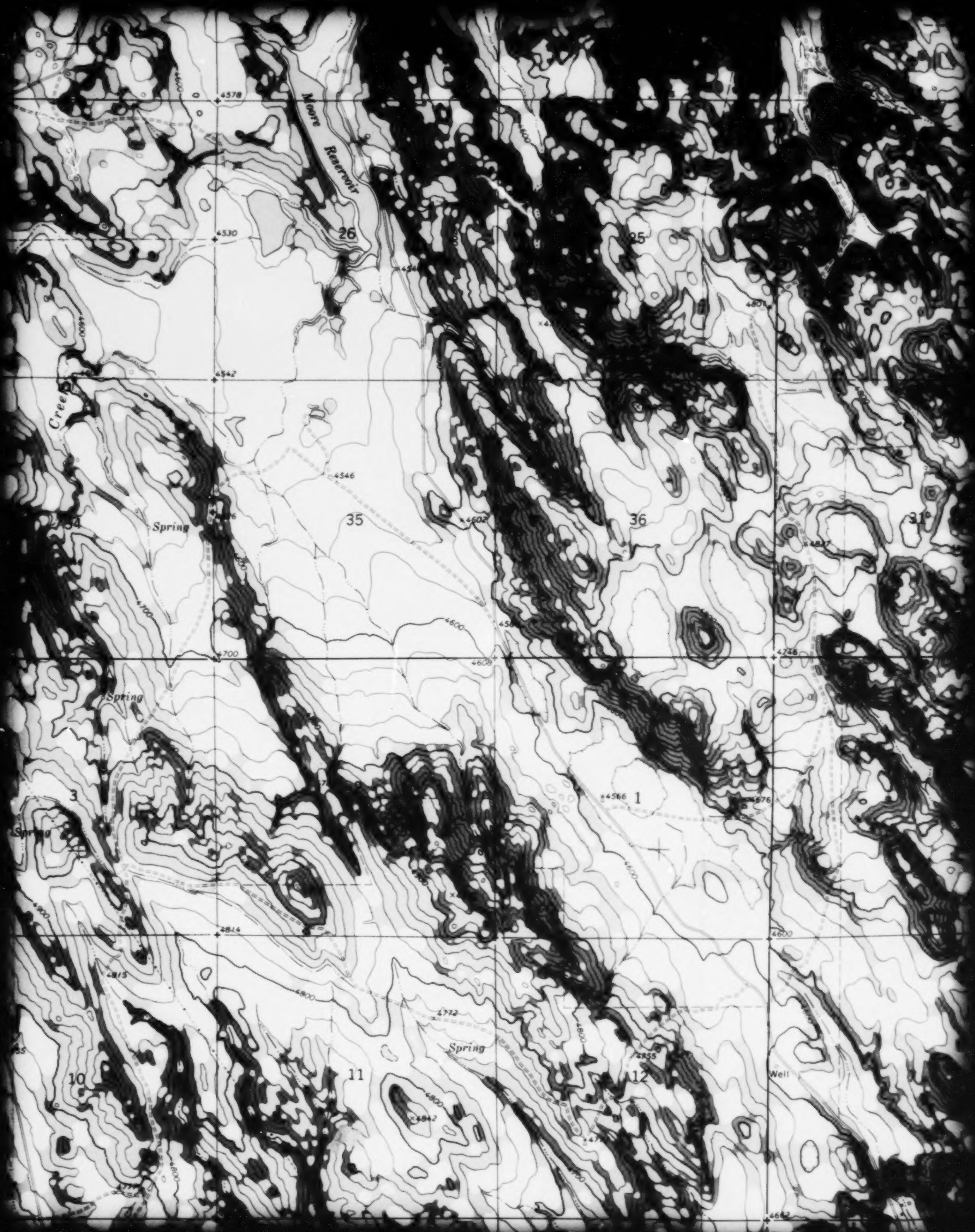


LAKE DE SMET EAST QUADRANGLE

WYOMING—JOHNSON CO.




27′30″
4924
20
4586
4591
4923
28
4600
4578
4530
4586
4756
4638
4542
4700
4800
SHERIDAN 29 MI.
26 MI. TO U.S. 14
(LAKE DE SMET WEST)
Creek
34
Spring
T. 52 N.
T. 51 N.
4856
4940
4846
4700
LAKE DE SMET CANAL
Spring
Spring
4920
5
4
BM 4797
3
25′
LAST CHANCE DITCH
4905
4919
4787
4900
4814
4815
Rock
4715
4755
BM 4711
9
4692
8
0
10
4918
Creek
Creek
4722


4578
4600
Moore Reservoir
4530
26
25
4801
4542
Creek
4546
35
36
34
Spring
4602
31
4827
4700
4600
4608
4700
4746
Spring
3
Spring
4566
1
4676
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4814
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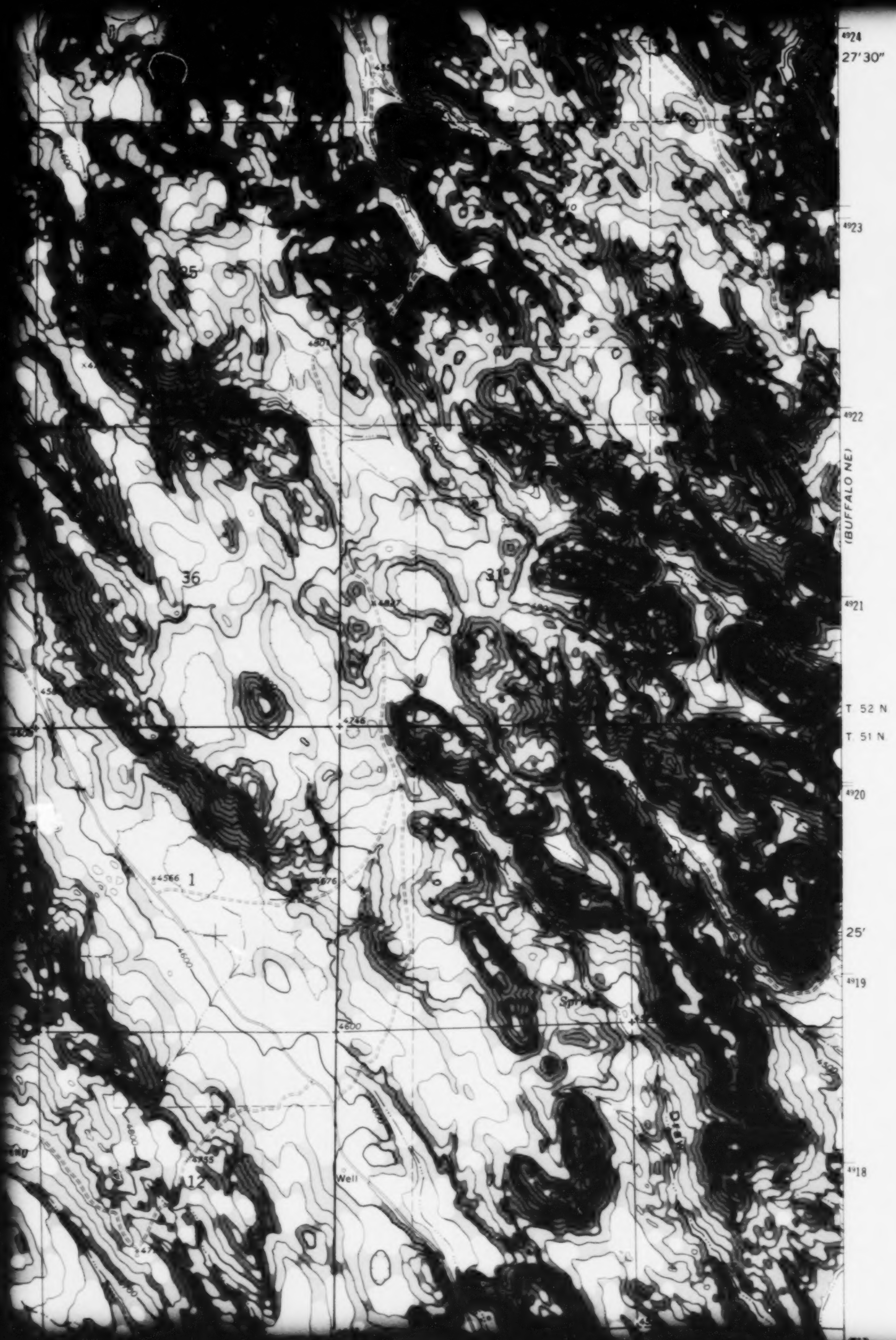
11
12
4755
4842
4800
Well
4662



4924
27′30″
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(BUFFALO NE)
36
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T. 51 N
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4566
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4676
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Spring
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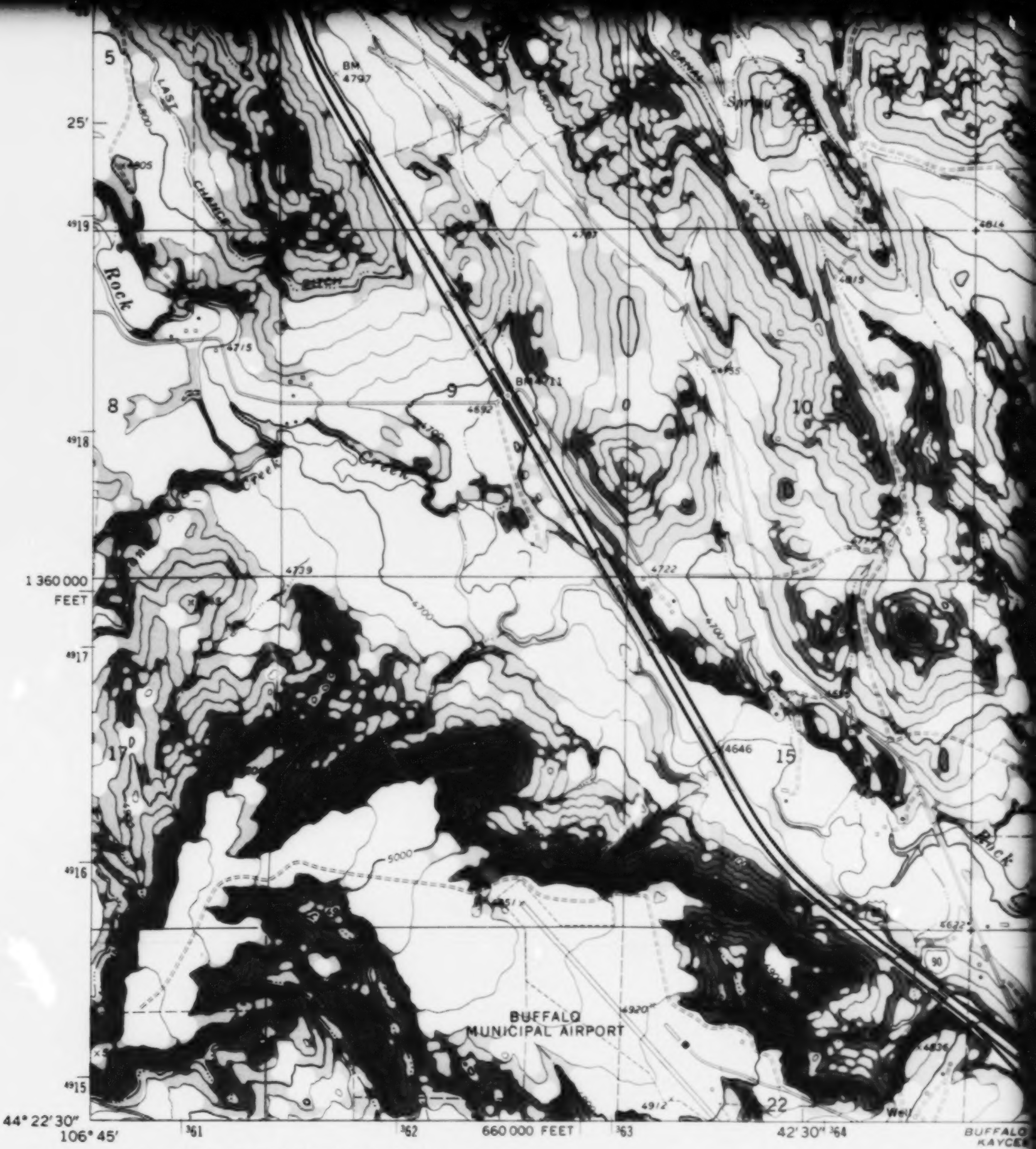
Well
4918

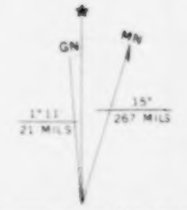


Mapped, edited, and published by the Geological Survey

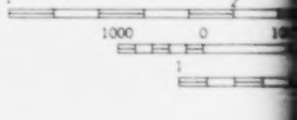
Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1969. Field checked 1970

Polyconic projection. 1927 North American datum
10,000-foot grid based on Wyoming coordinate system, east central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

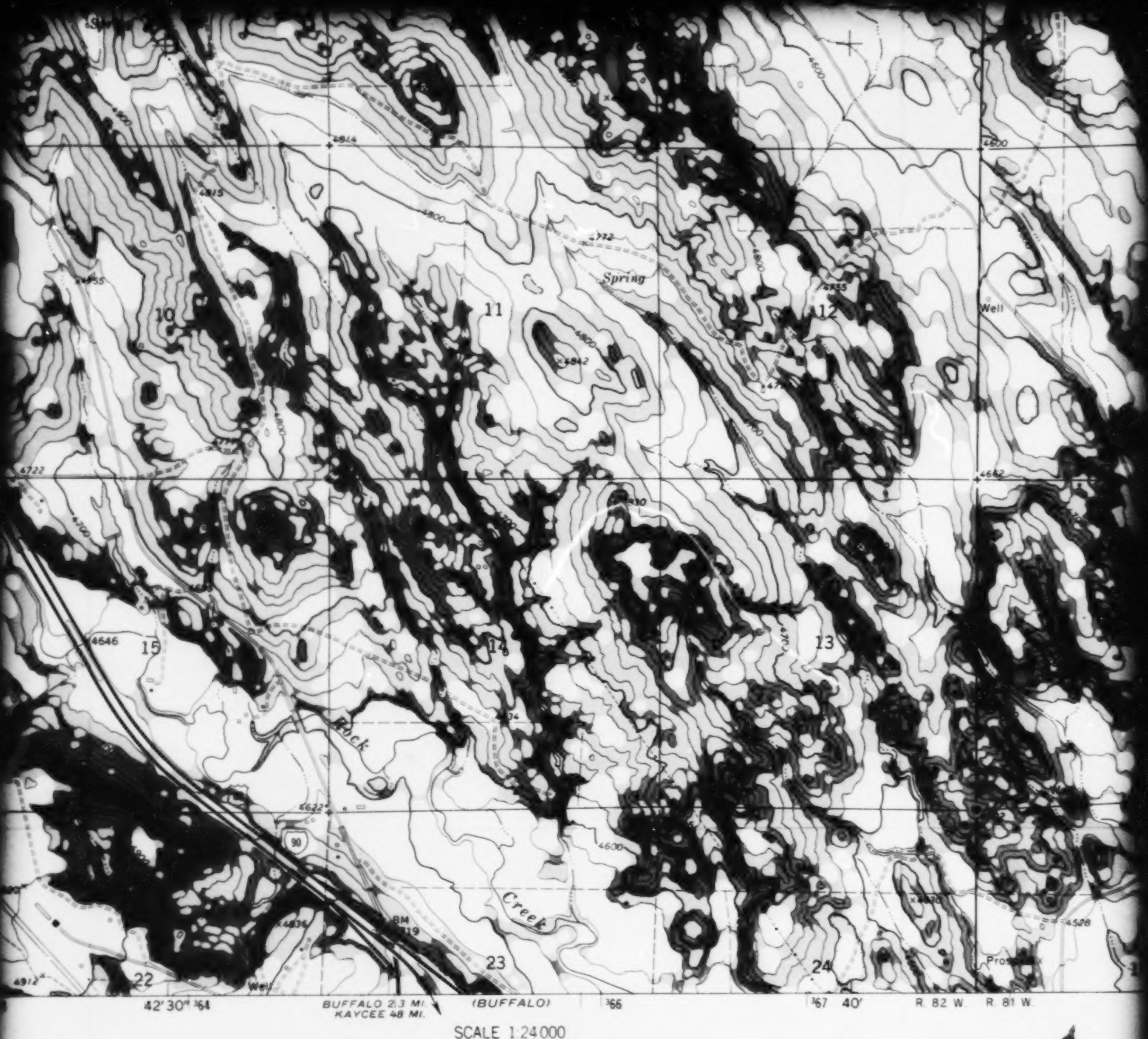


UTM GRID AND 1970 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

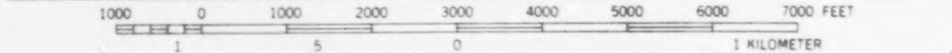


Note: The slope zones
photomechanical proc
of slope. Proximity of
false slope information
narrow drains and inci

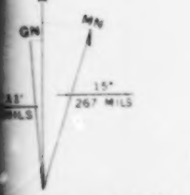
☆ GPO 781-902



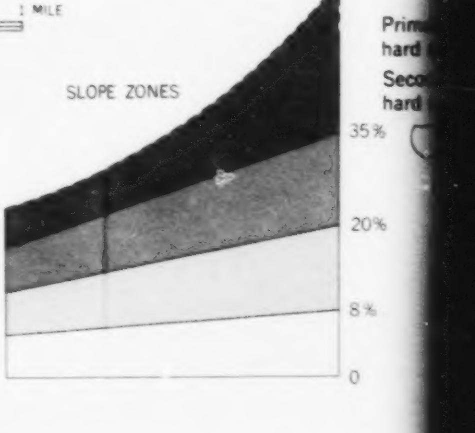
SCALE 1:24 000

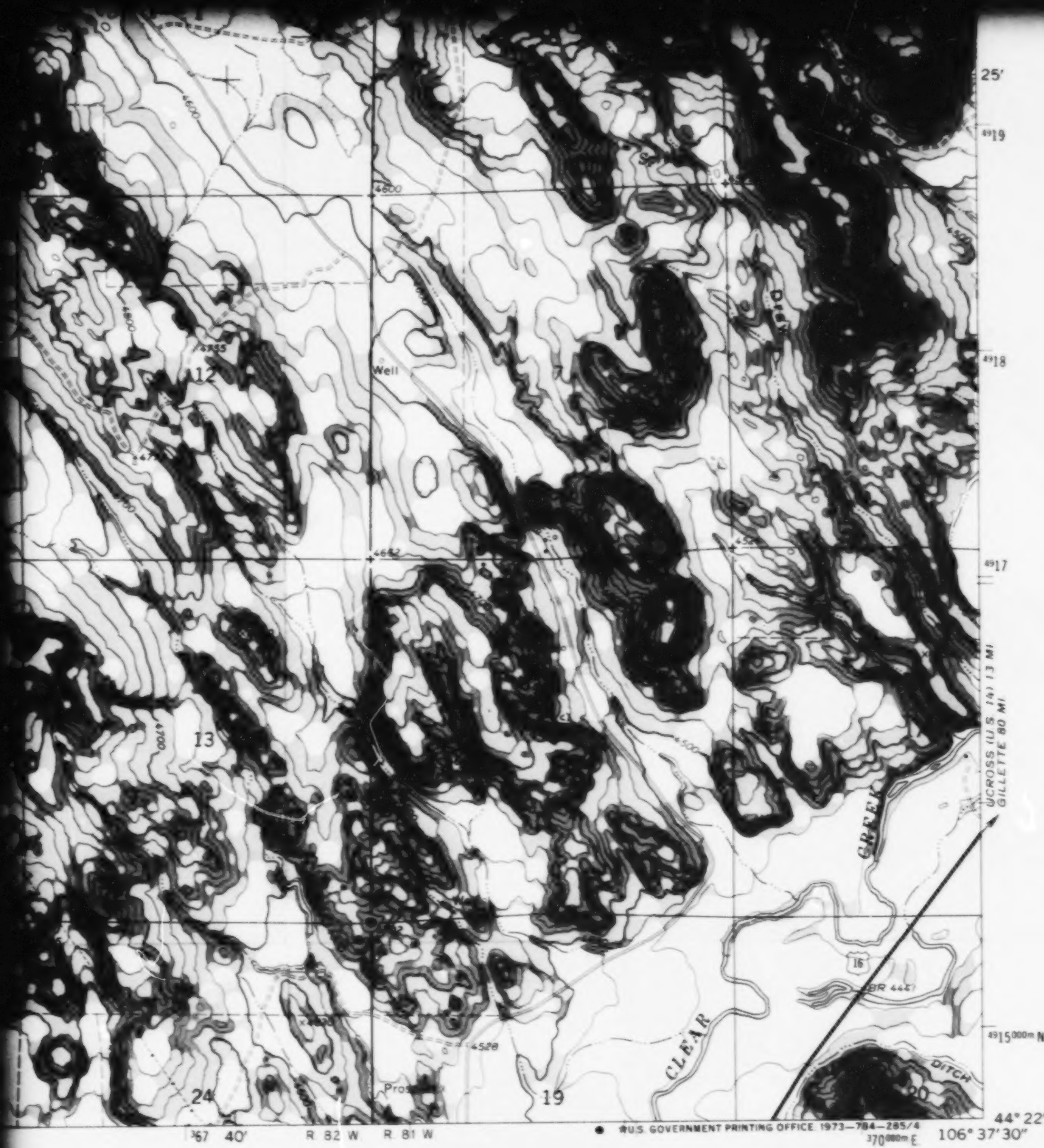


CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



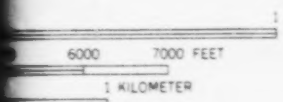
Note: The slope zones on this map are unedited. They were generated manually and by a photomechanical process which translates distance between adjacent contours into percentage of slope. Proximity of the same contour or absence of adjacent contours may have produced false slope information at small tops and depressions, on cuts and fills, along ridge crests, narrow drains and incised stream channels, along shores of open water, and at edges of the map



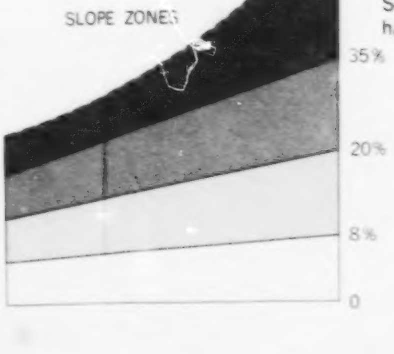


U.S. GOVERNMENT PRINTING OFFICE: 1973—784—285/4

(BUFFALO SE)



SLOPE ZONES



manually and by a
ntours into percentage
s may have produced
along ridge crests,
and at edges of the map

ROAD CLASSIFICATION

Primary highway, hard surface	━━━	Light-duty road, hard or improved surface	═══
Secondary highway, hard surface	━ ━ ━	Unimproved road	┅┅┅

Interstate Route   U. S. Route   State Route

LAKE DE SMET EAST, WYO.

N4422.5—W10637.5/7.5

1970

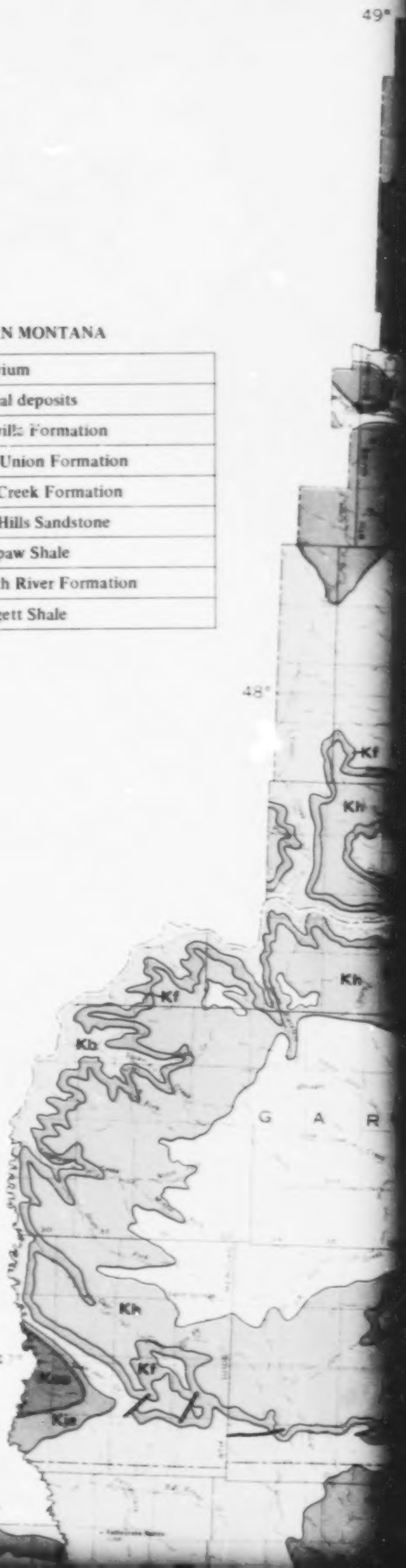
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

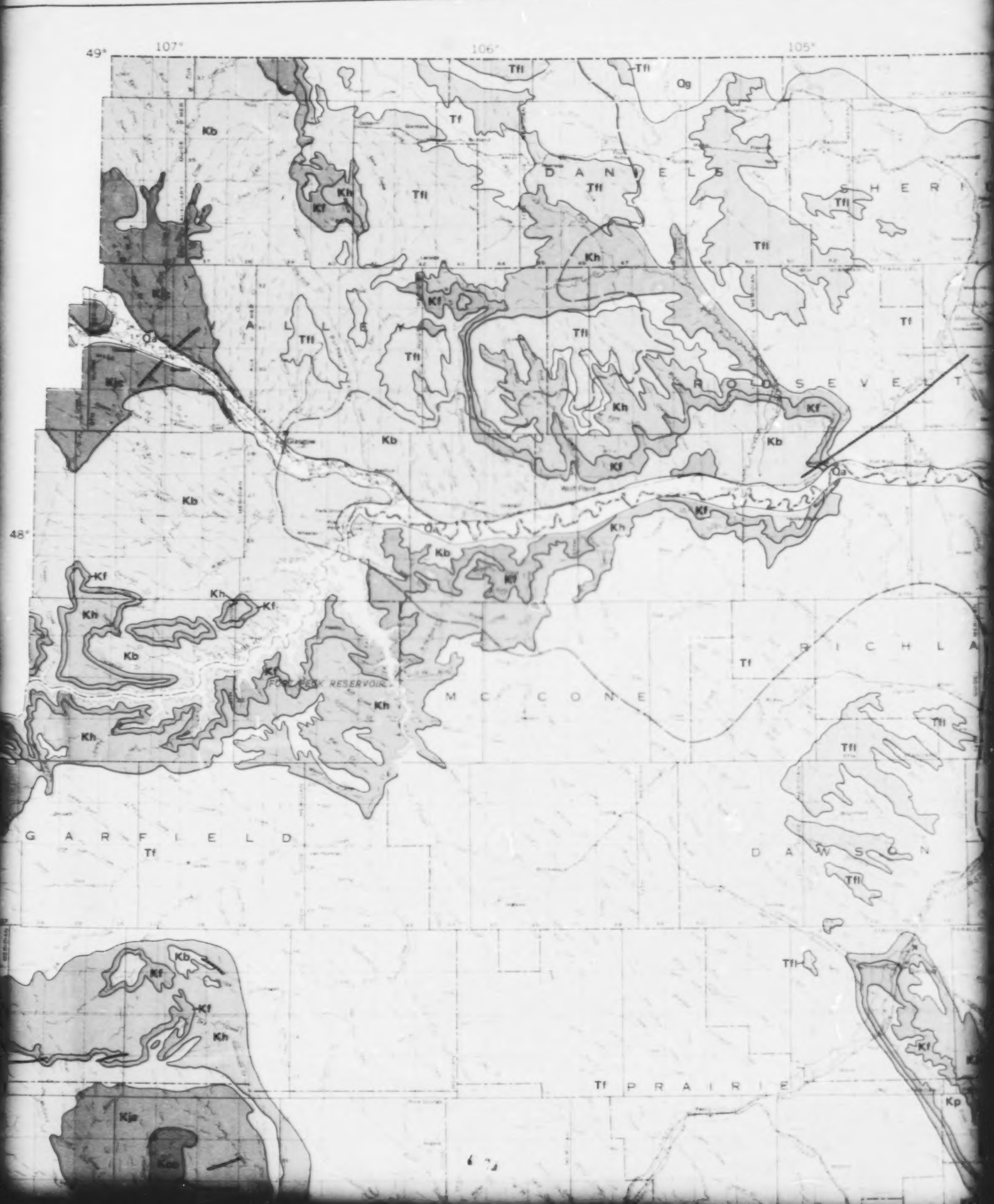
NORTHEASTERN MONTANA

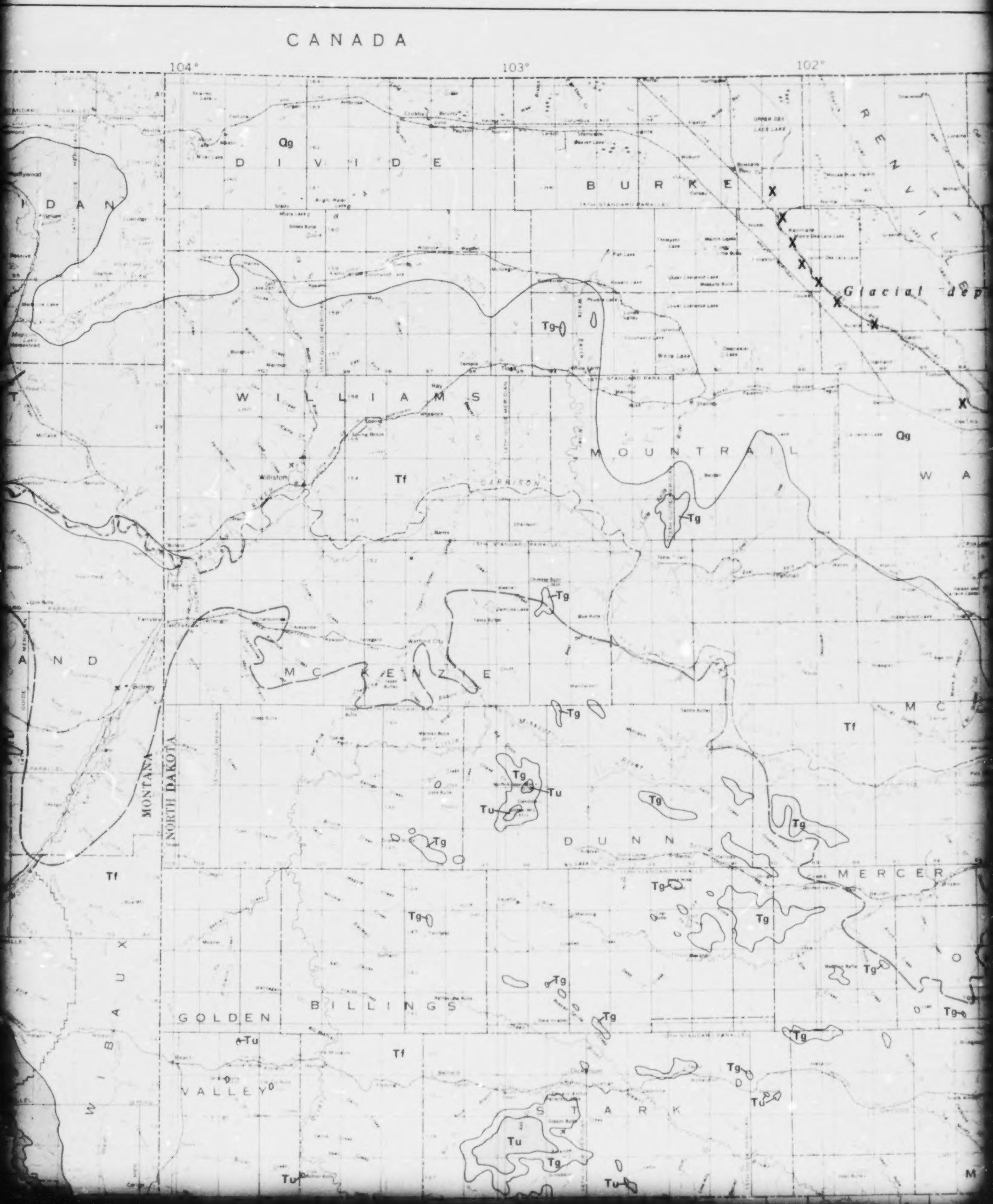
QUATERNARY	Qa	Alluvium
	Qg	Glacial deposits
TERTIARY	Tfl	Flaxville Formation
	Tf	Fort Union Formation
CRETACEOUS	Kh	Hell Creek Formation
	Kf	Fox Hills Sandstone
	Kb	Bearpaw Shale
	Kjc	Judith River Formation
		Claggett Shale

BIG SNOWY MOUNTAINS, BULL MOUNTAINS BASIN, AND ADJACENT AREAS IN CENTRAL MONTANA

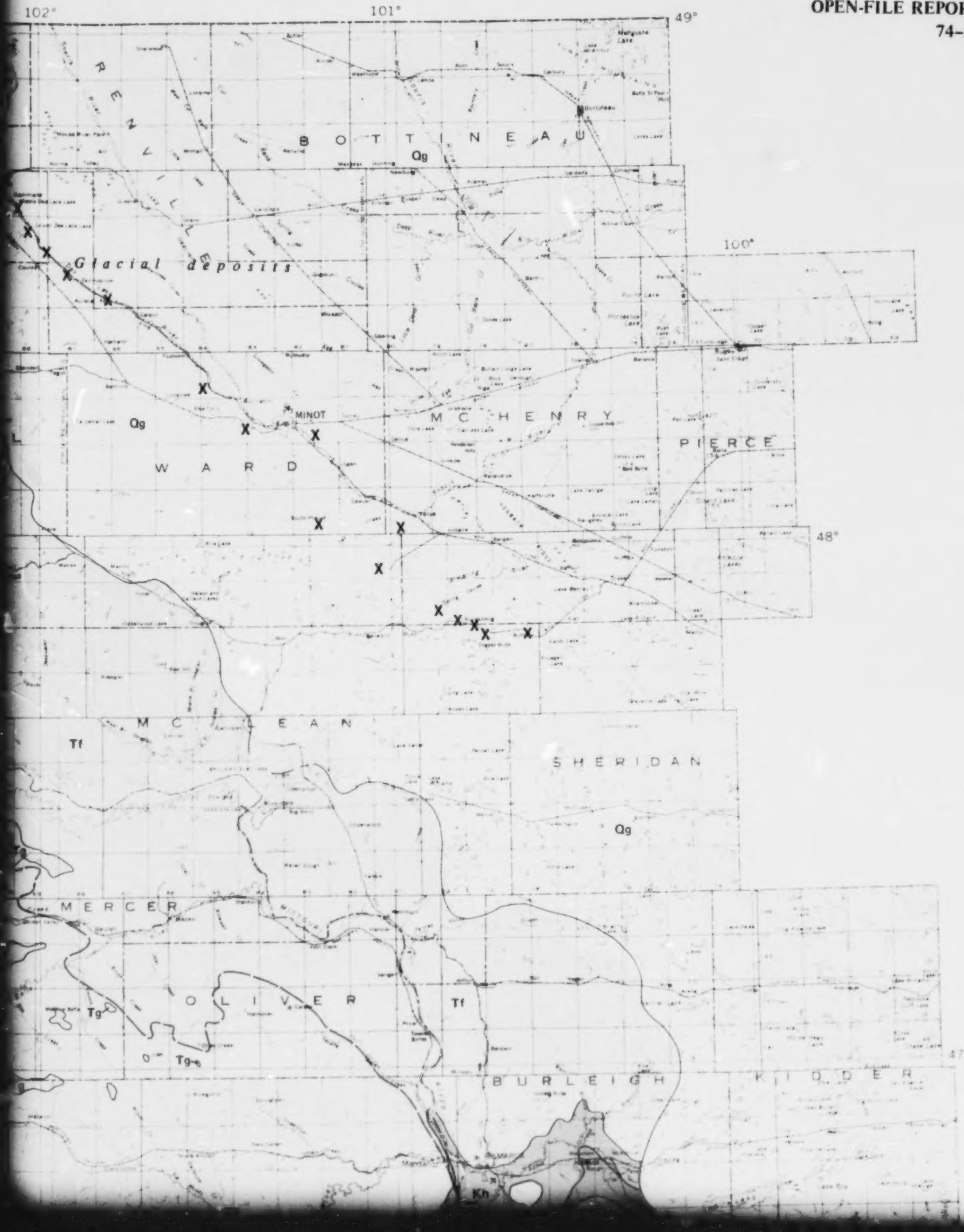
QUATERNARY	Qa	Alluvium
	Qt	Terrace deposit
TERTIARY	Tf	Fort Union Formation
CRETACEOUS	Kh	Hell Creek Formation
	Kb	Bearpaw Shale
	Kje	Judith River Formation
		Claggett Shale
		Eagle Sandstone
	Km	Colorado Shale
	KJk	Kootenai Formation
JURASSIC		Morrison Formation
		Ellis Group
PENNSYLVANIAN	PMq	Quadrant Formation
		Amsden Formation
MISSISSIPPIAN		Big Snowy Group
		Madison Group
CAMBRIAN	Єu	Snowy Range Formation
		Pilgrim Limestone
		Wolsey and Park Shales
		Flathead Sandstone
PRECAMBRIAN	pЄ	Belt shales

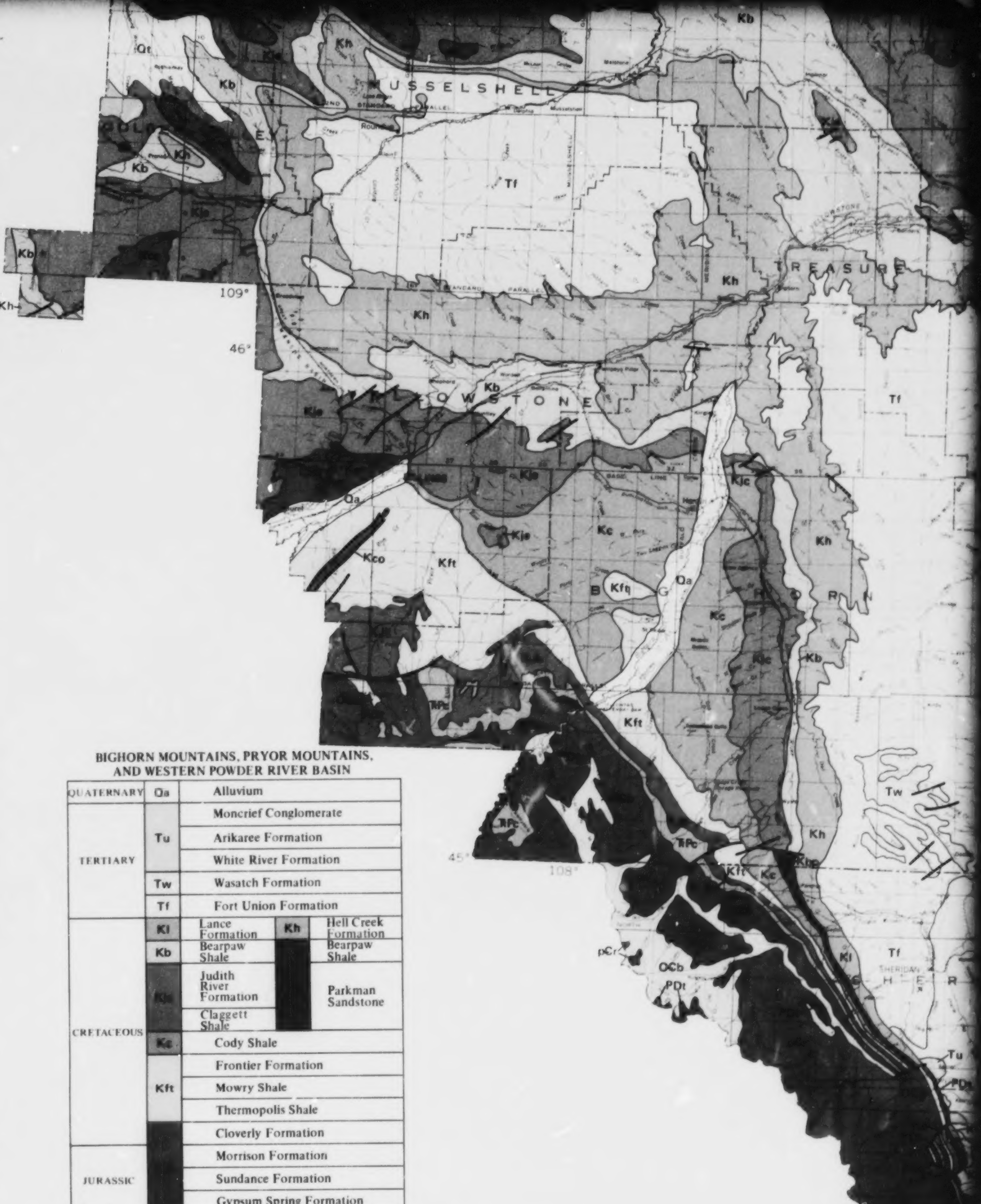



49°
107°
106°
105°
48°
D A N I E L S
S H E R I
V A L L E Y
R O O S E V E L T
R I C H L A
M C C O N E
G A R F I E L D
D A W S O N
P R A I R I E
FORT PECK RESERVOIR
Glasgow
Kb
Kf
Kh
Kjr
Kp
Qa
Qg
Tf
Tfl


CANADA
104°
103°
102°
Qg
DIVIDE
BURKE
RENVILLE
Glacial dep
IDAN
Tg
WILLIAMS
MOUNTRAIL
Qg
WA
Williston
Tf
GARRISON
MCKENZIE
AND
Tg
MC
Tf
MONTANA
NORTH DAKOTA
Tg
Tu
Tu
Tg
DUNN
Tg
Tg
MERCER
Tf
Tg
Tg
Tg
Tg
Tg
O
Tg
WIBAUX
GOLDEN
BILLINGS
Tg
Tg
Tu
Tf
Tg
VALLEY
STARK
Tu
Tu
Tg
Tu
Tu
M

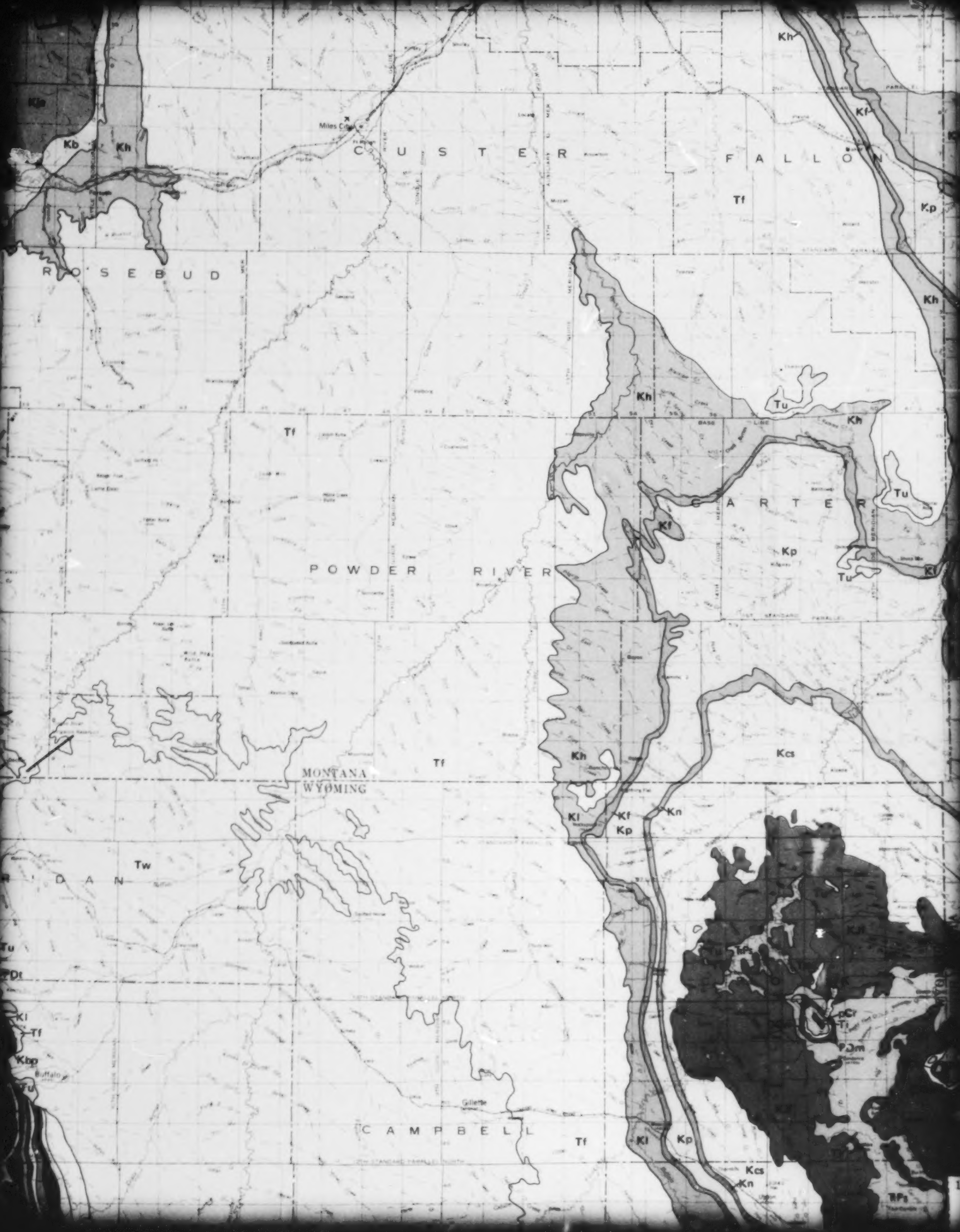
OPEN-FILE REPORT
74-50

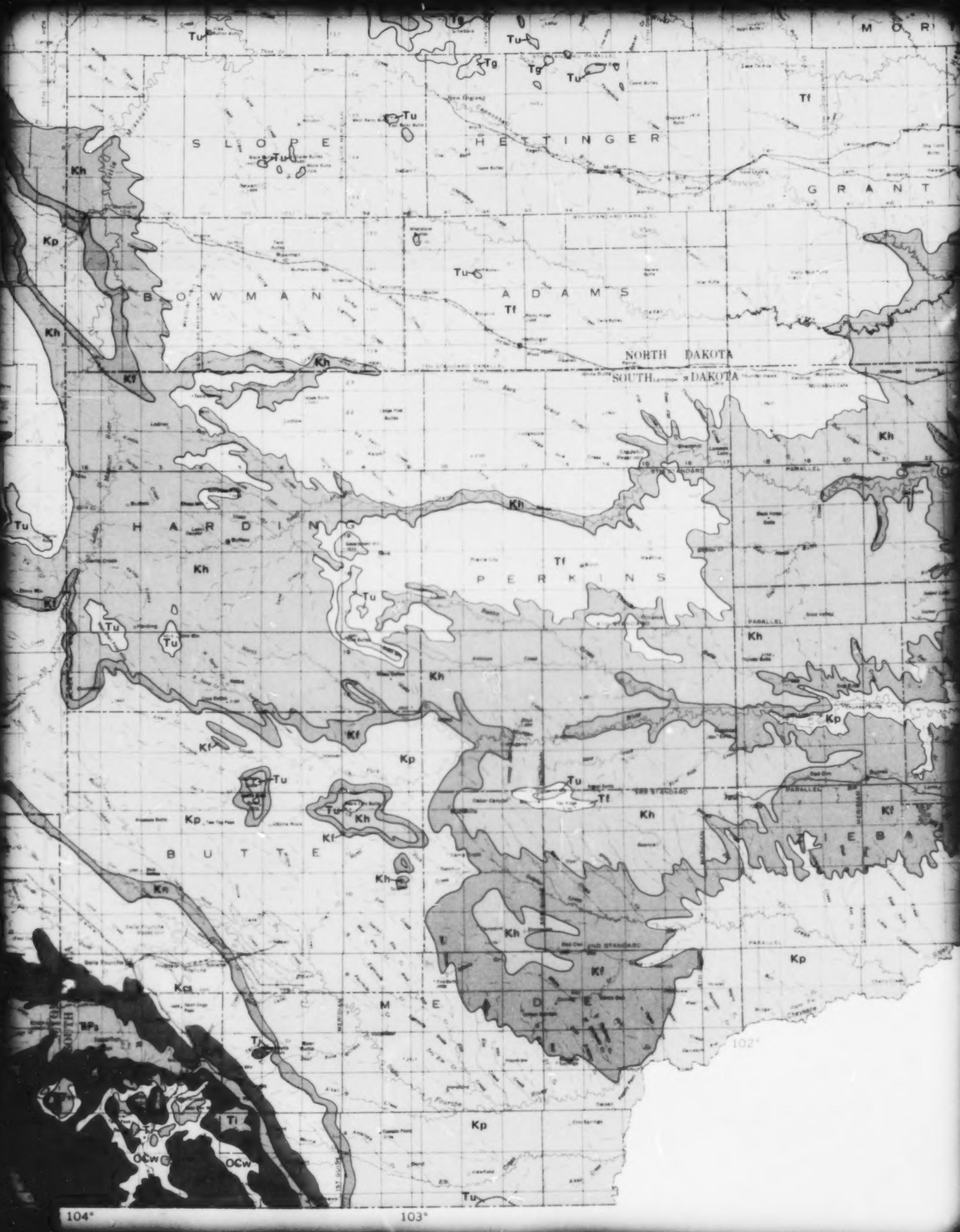


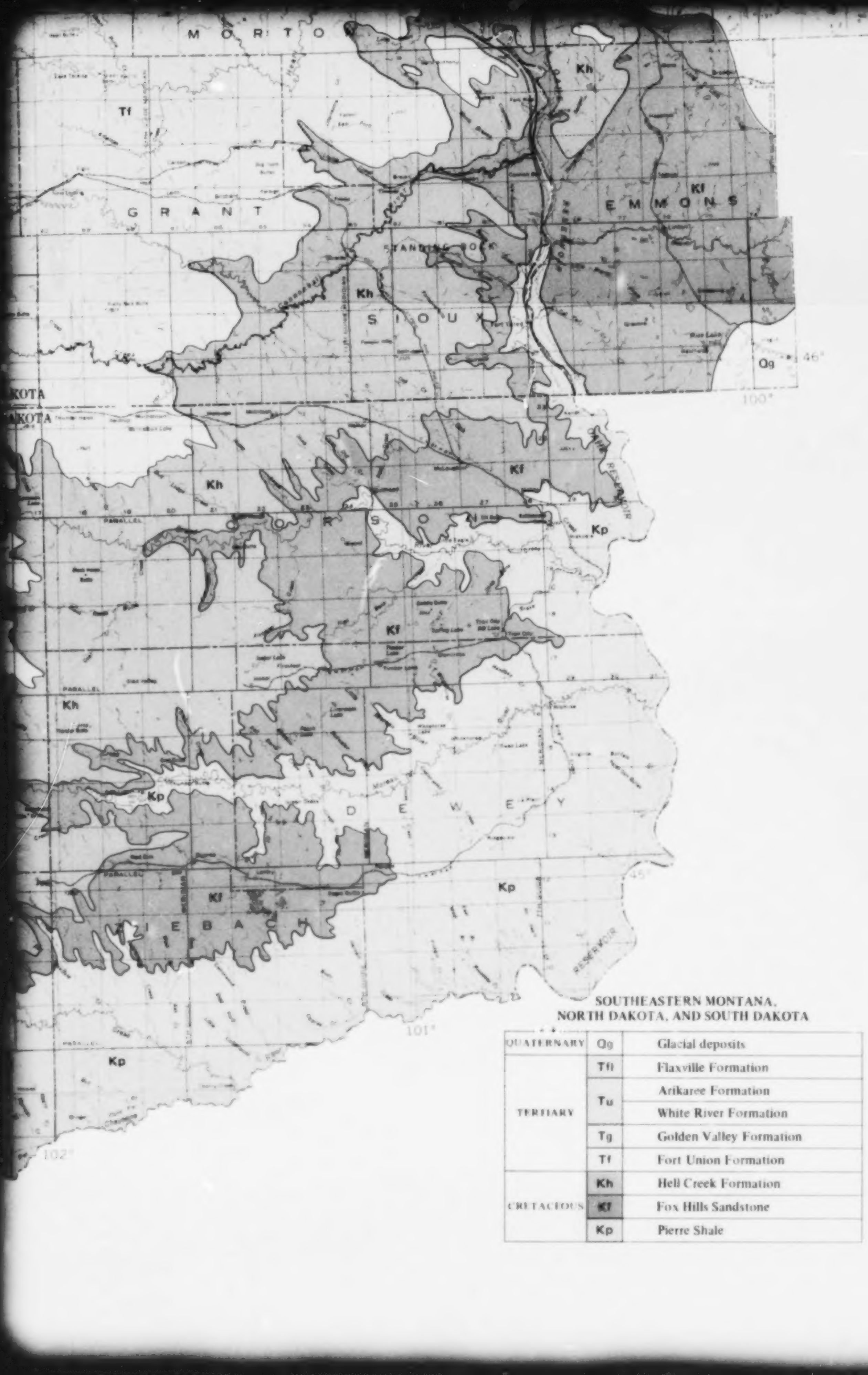


BIGHORN MOUNTAINS, PRYOR MOUNTAINS, AND WESTERN POWDER RIVER BASIN

QUATERNARY	Qa	Alluvium		
TERTIARY	Tu	Moncrief Conglomerate		
		Arikaree Formation		
		White River Formation		
	Tw	Wasatch Formation		
	Tf	Fort Union Formation		
CRETACEOUS	Kl	Lance Formation	Kh	Hell Creek Formation
	Kb	Bearpaw Shale		Bearpaw Shale
	Kjc	Judith River Formation		Parkman Sandstone
		Claggett Shale		
	Kc	Cody Shale		
	Kft	Frontier Formation		
		Mowry Shale		
		Thermopolis Shale		
		Cloverly Formation		
JURASSIC		Morrison Formation		
		Sundance Formation		
		Gypsum Spring Formation		
TRIASSIC	TRPc	Chugwater Formation		
PERMIAN		Goose Egg Formation		
PENNSYLVANIAN		Tensleep Sandstone		
		Amsden Formation		


Kh
Kf
Kp
Kb
Kh
Miles City
CUSTER
FALLON
Tf
ROSEBUD
Kh
Tu
Kh
Tf
BASE LINE
Tu
CARTER
Kf
Kp
Tu
Kl
POWDER RIVER
Kcs
Tf
Kh
MONTANA
WYOMING
Kl
Kf
Kp
Kn
Tw
DAN
Tu
Dt
Kl
Tf
Kbp
Buffalo
Tu
pCr
Ti
Gillette
CAMPBELL
Tf
Kl
Kp
Kcs
Kn


M O R
Tu
Tg
Tf
S L O P E
H E T T I N G E R
G R A N T
Kh
Kp
B O W M A N
A D A M S
NORTH DAKOTA
SOUTH DAKOTA
Kf
H A R D I N G
P E R K I N S
B U T T E
Z I E B A
M E
D E
Ka
Ti
OCw
102°
104°
103°



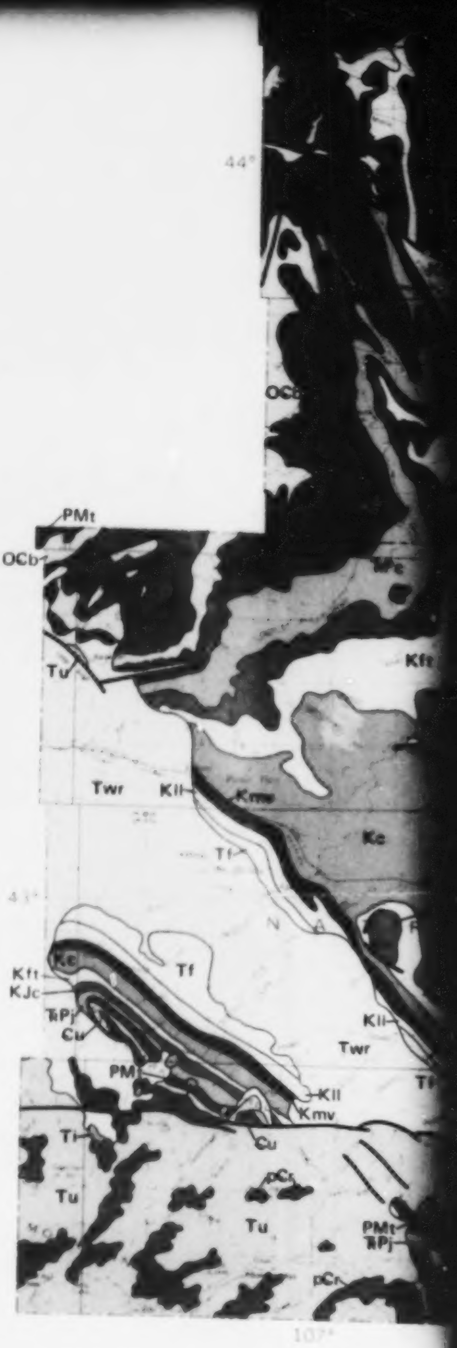
SOUTHEASTERN MONTANA,
NORTH DAKOTA, AND SOUTH DAKOTA

QUATERNARY	Qg	Glacial deposits
TERTIARY	Tfl	Flaxville Formation
	Tu	Arikaree Formation
		White River Formation
	Tg	Golden Valley Formation
	Tf	Fort Union Formation
CRETACEOUS	Kh	Hell Creek Formation
	Kf	Fox Hills Sandstone
	Kp	Pierre Shale

PENNSYLVANIAN	■	Tensleep Sandstone
		Amsden Formation
MISSISSIPPIAN		Madison Limestone
DEVONIAN		Jefferson Formation
		Souris River Formation
		Beartooth Butte Formation
ORDOVICIAN	OCb	Bighorn Dolomite
CAMBRIAN		Gallatin and Gros Ventre Fms
		Flathead Sandstone
PRECAMBRIAN	■	Crystalline rocks

SOUTHWESTERN POWDER RIVER BASIN, CASPER ARCH, AND SOUTHEASTERN WIND RIVER BASIN

QUATERNARY	Qs	Windblown sand	
TERTIARY	Tu	Ogallala Formation	
		Arikaree Formation	
		White River Formation	
	Ti	Intrusive rocks	
	Twr	Wagon Bed Formation	
		Wind River Formation	
	Tf	Fort Union Formation	
CRETACEOUS	Kl	Lance Formation	Klf
	Kf	Fox Hills Ss and Lewis Sh	Kll
	■	Mesaverde Formation	
	Kc	Cody Shale	
	Kft	Frontier Formation	
		Mowry Shale	
		Thermopolis Shale	
	■	Cloverly Formation	
JURASSIC		Morrison Formation	
		Sundance Formation	
TRIASSIC	ŦPj	Jelm Formation	
		Red Peak Formation	
		Goose Egg Formation	
PERMIAN			
PENNSYLVANIAN	■	Tensleep Sandstone	
		Amsden Formation	
MISSISSIPPIAN		Madison Limestone	
CAMBRIAN	Cu	Gallatin Limestone, Gros Ventre Formation, and Flathead Ss	
PRECAMBRIAN	■	Crystalline rocks	



Base map from U.S. Geological Survey maps of
Wyoming (1967), Montana (1968), North Dakota (1963),
and South Dakota (1963)

☆ U.S. GOVERNMENT PRINTING OFFICE : 1974 — 781-822

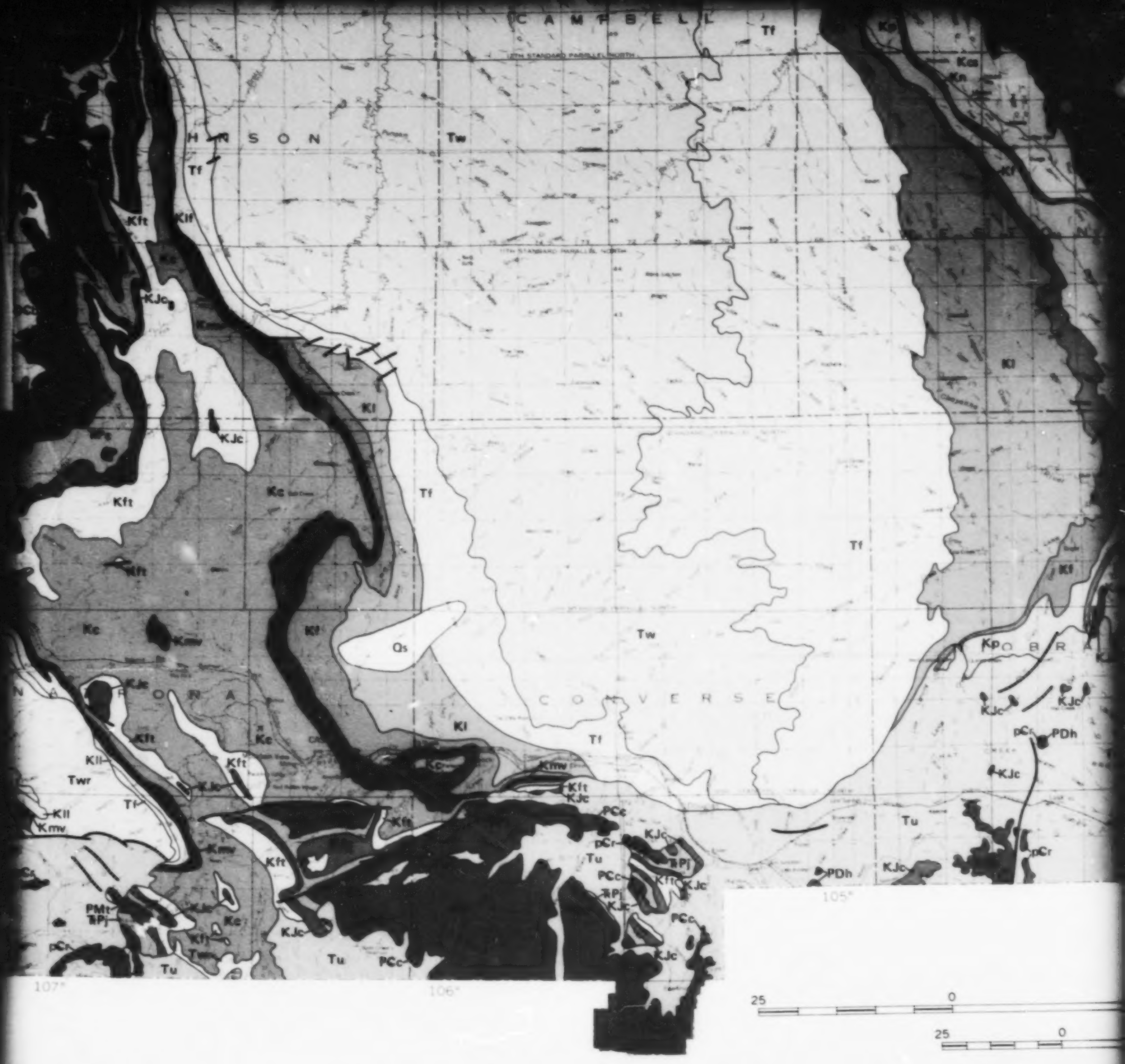


PLATE A–3. GEOLOGIC MAP OF THE N

Prepared for

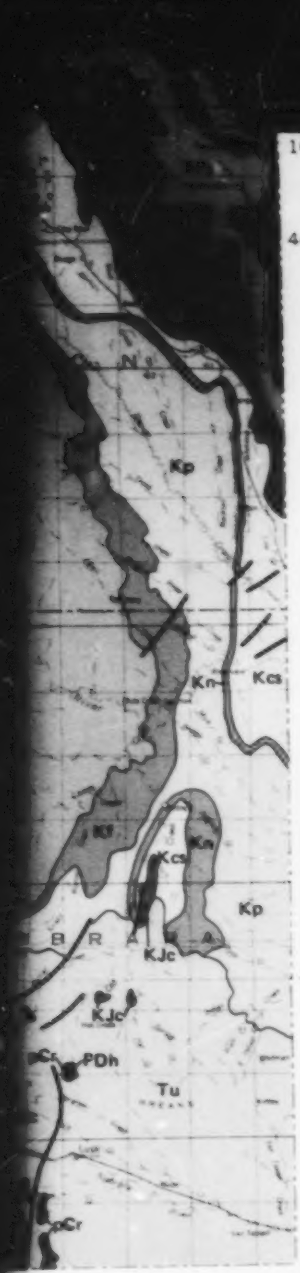
THE NORTHERN GREAT PLAINS R

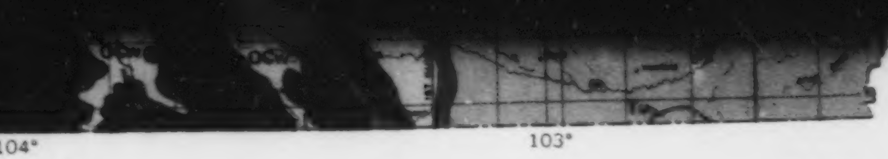
By

William R. Keefer

U.S. Geological Surve

1974





LARAMIE MOUNTAINS AND SOUTHERN POWDER RIVER BASIN

TERTIARY	Tu	Ogallala Formation		
		Arikaree Formation		
		White River Formation		
	Tw	Wasatch Formation		
	Tf	Fort Union Formation		
CRETACEOUS	Kl	Lance Formation		
	Kf	Fox Hills Sandstone		
		Lewis Shale		
	[illegible]	Mesaverde Formation		
	Kc	Cody Shale		
	Kft	Frontier Formation		
		Mowry Shale		
		Thermopolis Shale		
	[illegible]	Cloverly Formation		
JURASSIC		Morrison Formation		
		Sundance Formation		
TRIASSIC	TRPj	Jelm Formation		
		Red Peak Formation		
PERMIAN		Goose Egg Formation		
PENNSYLVANIAN	[illegible]	Casper Formation	[illegible]	Hartville Formation
MISSISSIPPIAN		Madison Limestone		Guernsey Formation
DEVONIAN		Not present		
CAMBRIAN		Flathead Sandstone		Not present
PRECAMBRIAN	[illegible]	Crystalline rocks		

BLACK HILLS AND EASTERN POWDER RIVER BASIN

TERTIARY	Tu	White River Formation		
	[illegible]	Intrusive rocks		
	Tw	Wasatch Formation		
	Tf	Fort Union Formation		
CRETACEOUS	[illegible]	Lance Formation	[illegible]	He Fo
	[illegible]	Fox Hills Sandstone		
	Kp	Pierre Shale		
	[illegible]	Niobrara Formation		
	Kcs	Carlile Shale		
		Greenhorn Formation		
		Belle Fourche Shale		
		Mowry Shale		
		Newcastle Sandstone		
		Skull Creek Shale		
	[illegible]	Fall River Formation		
		Lakota Formation		
JURASSIC		Morrison Formation		
		Sundance Formation		
		Gypsum Spring Formatio		
TRIASSIC	TRPs	Spearfish Formation		
PERMIAN		Minnekahta Limestone		
		Opeche Formation		
PENNSYLVANIAN	[illegible]	Minnelusa Formation		
MISSISSIPPIAN		Pahasapa Limestone		
DEVONIAN		Englewood Limestone		
ORDOVICIAN	OCw	Whitewood Dolomite		
		Winnepeg Formation		
CAMBRIAN		Deadwood Formation		
PRECAMBRIAN	[illegible]	Crystalline rocks		

SCALE 1:1 000 000

25 50 75 100 MILES

0 25 50 75 100 KILOMETERS

THE NORTHERN GREAT PLAINS

ared for

LAINS RESOURCE PROGRAM

By

R. Keefer

ogical Survey

1974

BLACK HILLS AND ASTERN POWDER RIVER BASIN

Tu	White River Formation		
Ti	Intrusive rocks		
Tw	Wasatch Formation		
Tf	Fort Union Formation		
Kl	Lance Formation	Kh	Hell Creek Formation
[illegible]	Fox Hills Sandstone		
Kp	Pierre Shale		
[illegible]	Niobrara Formation		
Kcs	Carlile Shale		
	Greenhorn Formation		
	Belle Fourche Shale		
	Mowry Shale		
	Newcastle Sandstone		
	Skull Creek Shale		
[illegible]	Fall River Formation		
	Lakota Formation		
	Morrison Formation		
	Sundance Formation		
	Gypsum Spring Formation		
Ps	Spearfish Formation		
	Minnekahta Limestone		
	Opeche Formation		
[illegible]	Minnelusa Formation		
	Pahasapa Limestone		
	Englewood Limestone		
OCw	Whitewood Dolomite		
	Winnepeg Formation		
	Deadwood Formation		
[illegible]	Crystalline rocks		

EXPLANATION

Contact

Fault

Approximate southern limit of glacial drift

Bedrock units between this line and the line marking the contact with glacial deposits are well exposed along stream drainages but only discontinuously exposed in interstream divide areas

X

Limited exposure of Fort Union Formation

SOURCES OF DATA

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U.S. Geological Survey: Unpub. geologic mapping.

This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

UNITED STATES
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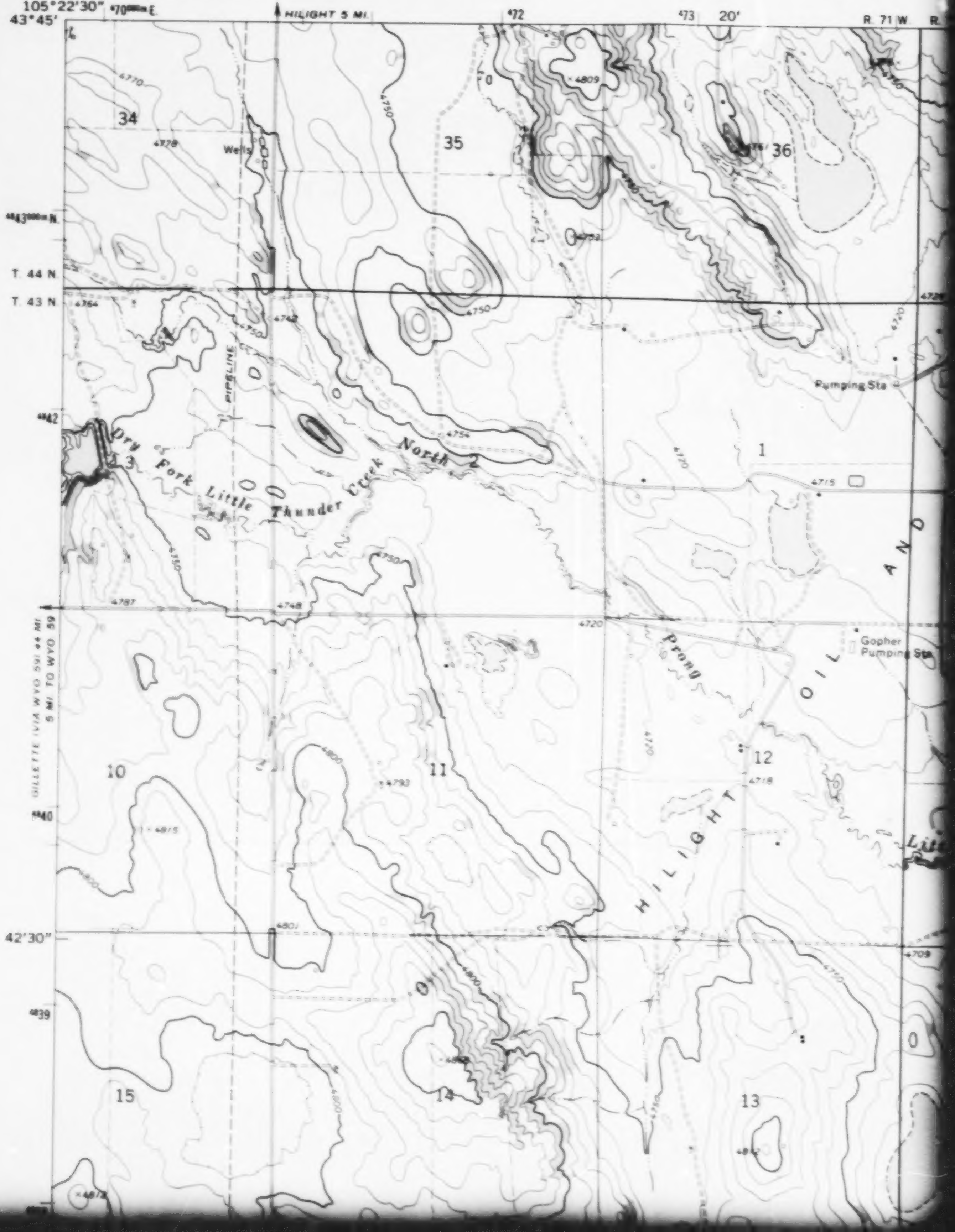
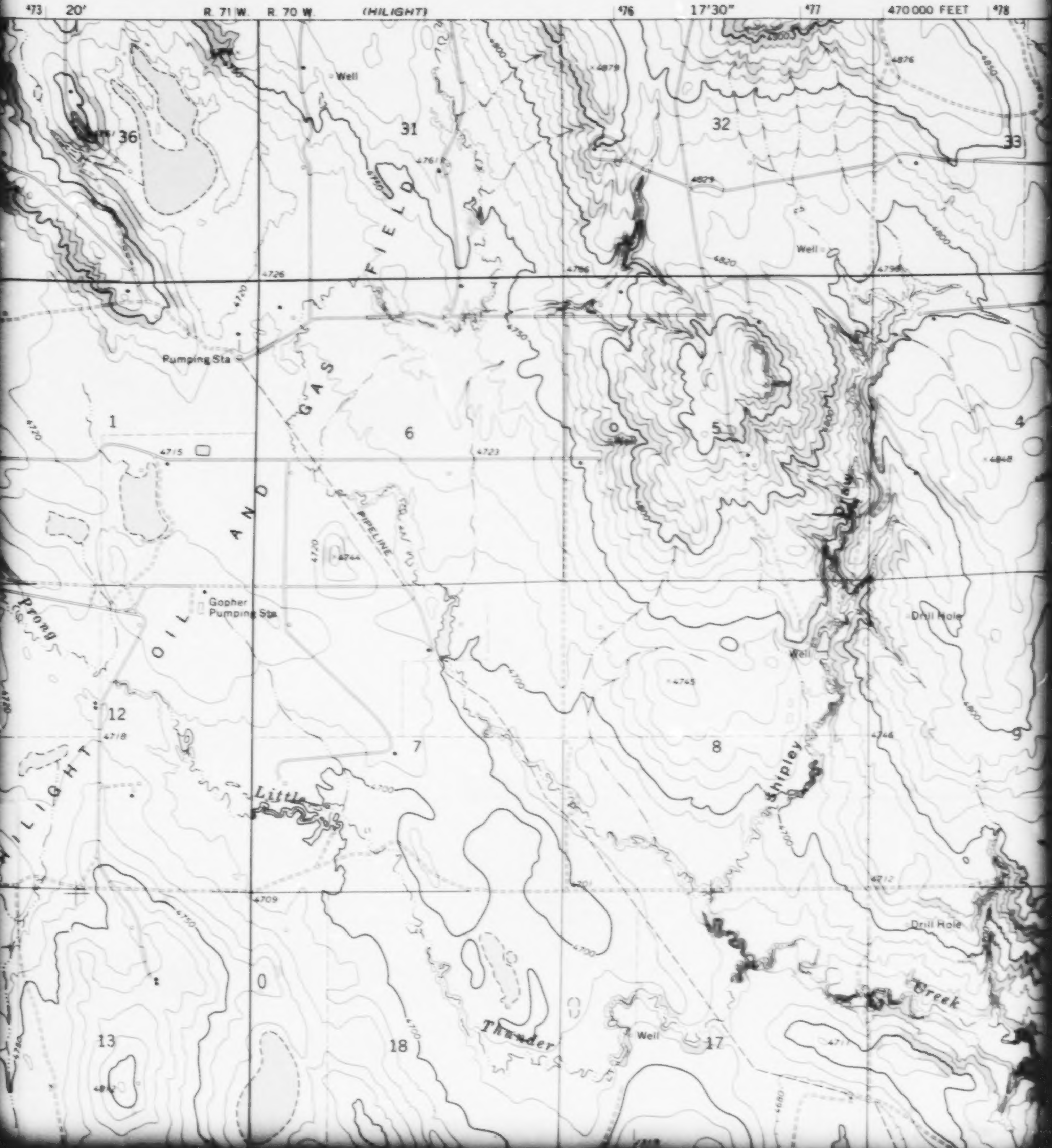
GEOLOGICAL SURVEY



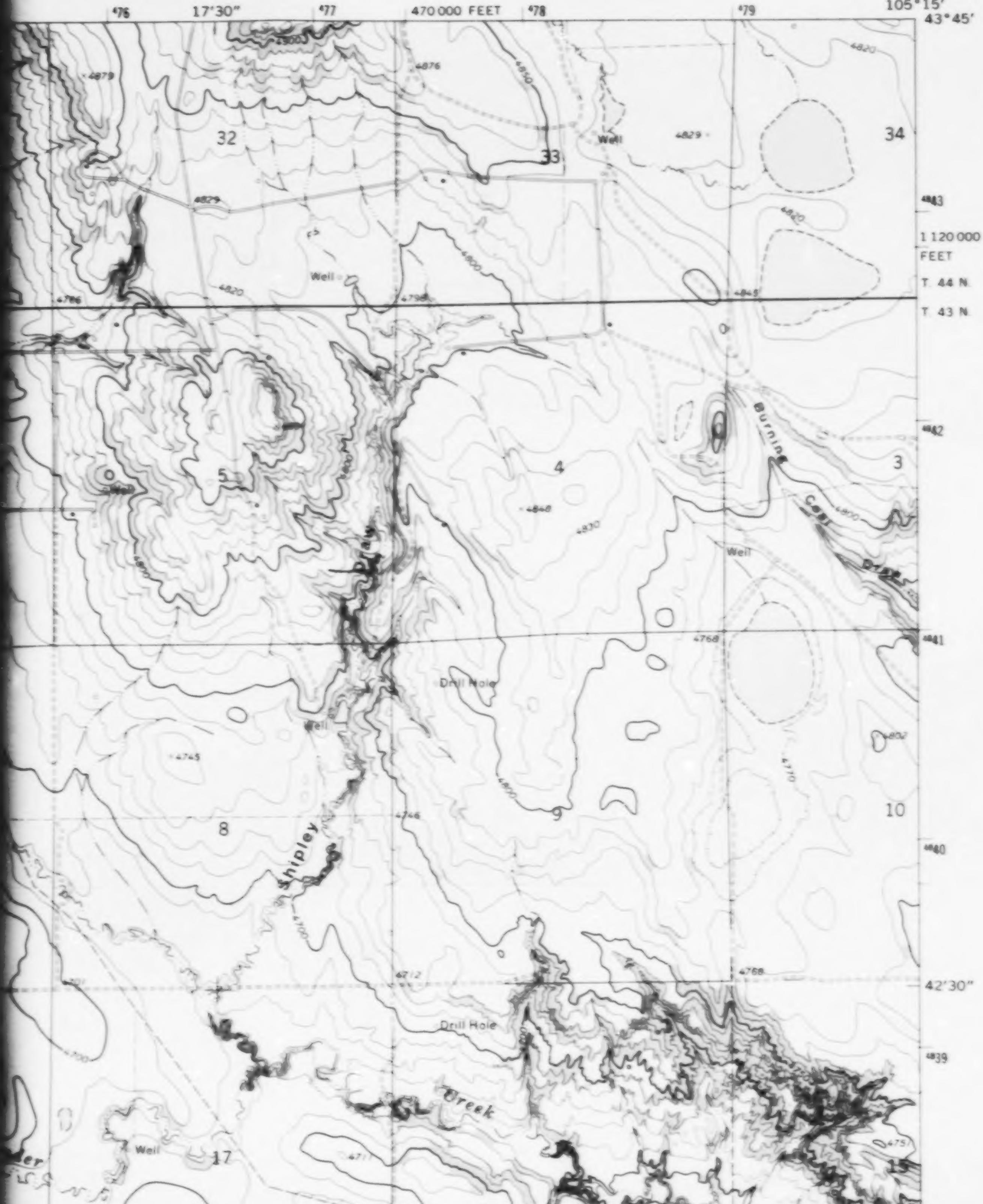
SLOPE MAP

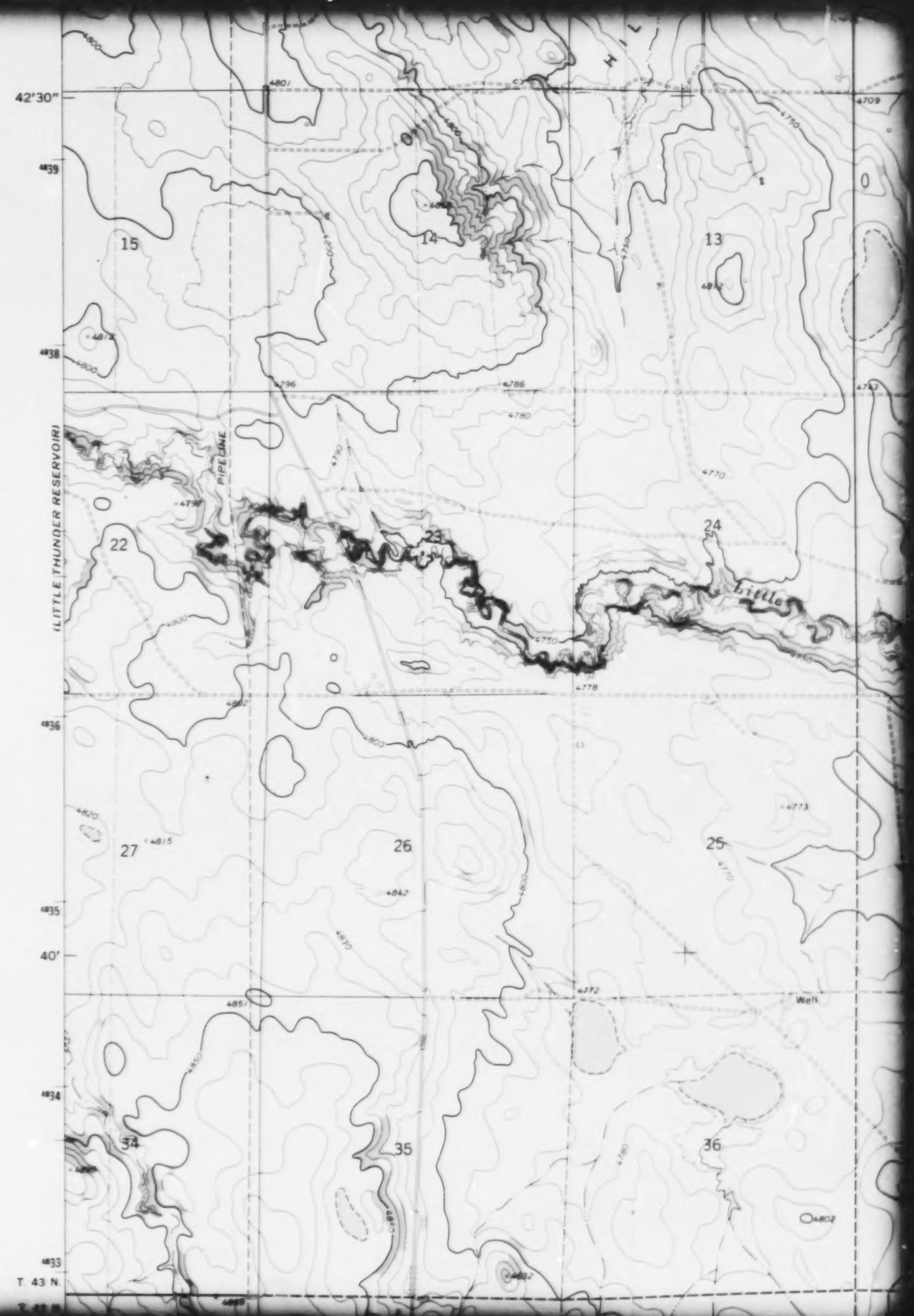
RE

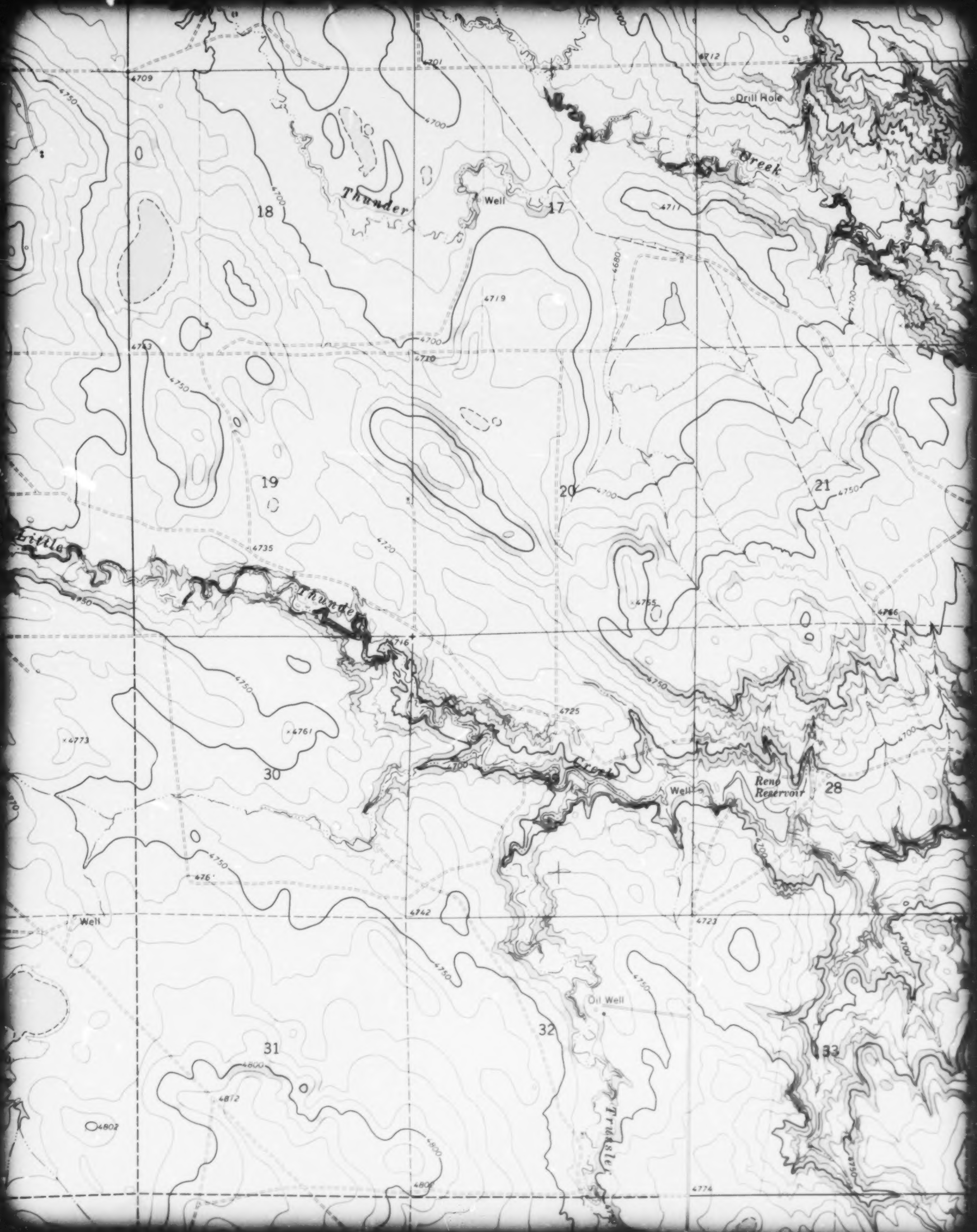

473
20'
R. 71 W.
R. 70 W.
(HILIGHT)
476
17'30"
477
470 000 FEET
478
Well
36
31
32
33
4879
4900
4876
4829
4761
4726
4720
4796
4820
4798
4800
FIELD
Pumping Sta
GAS
1
6
5
4
4715
4723
4848
AND
PIPELINE
4744
Gopher
Pumping Sta
Prong
OIL
Drill Hole
Well
Draw
4745
12
4718
7
8
9
4746
Shipley
Little
HILIGHT
4709
4712
Drill Hole
Creek
13
4842
18
Thunder
Well
17
4700
4680

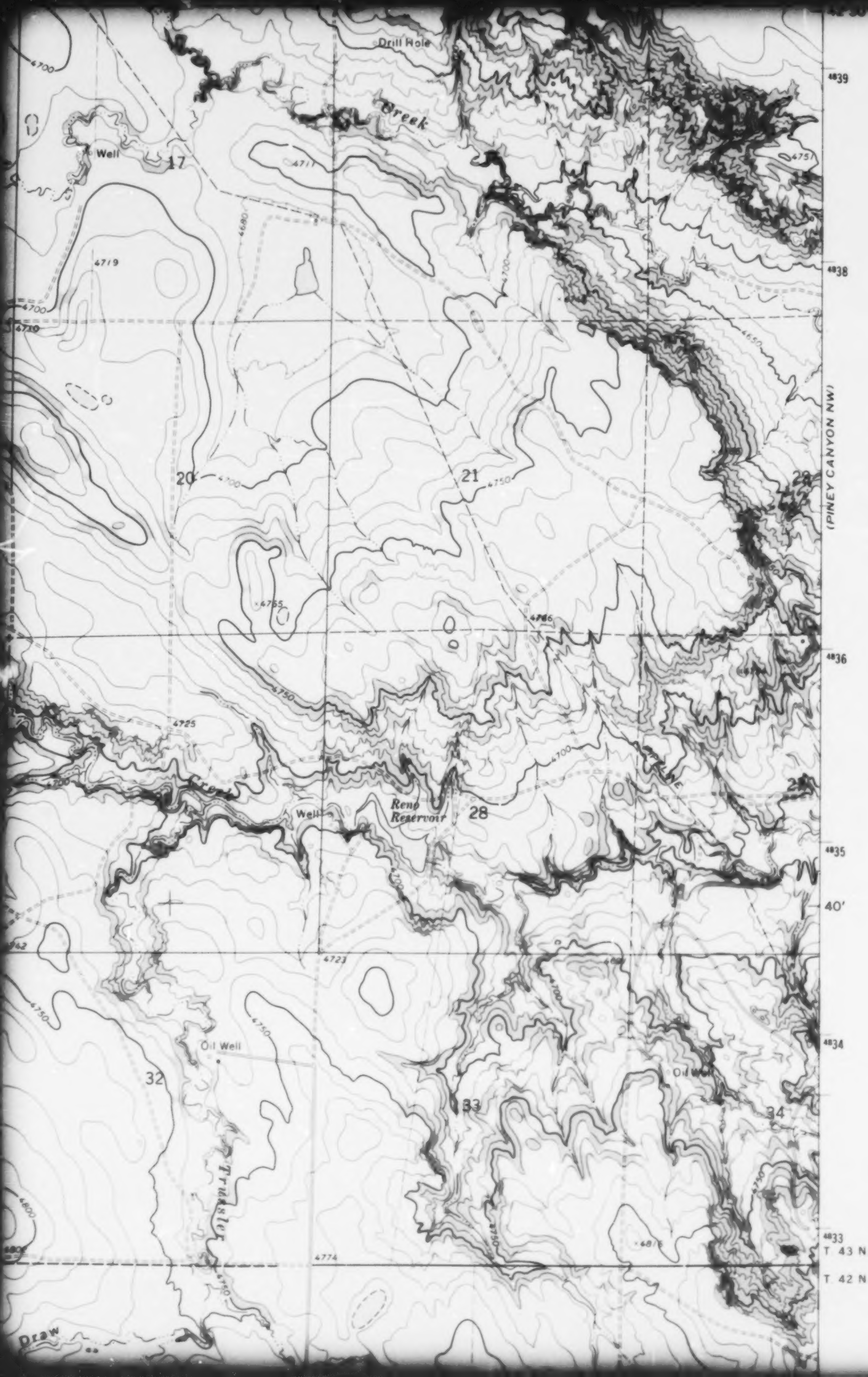
RENO RESERVOIR QUADRANGLE
WYOMING—CAMPBELL CO.

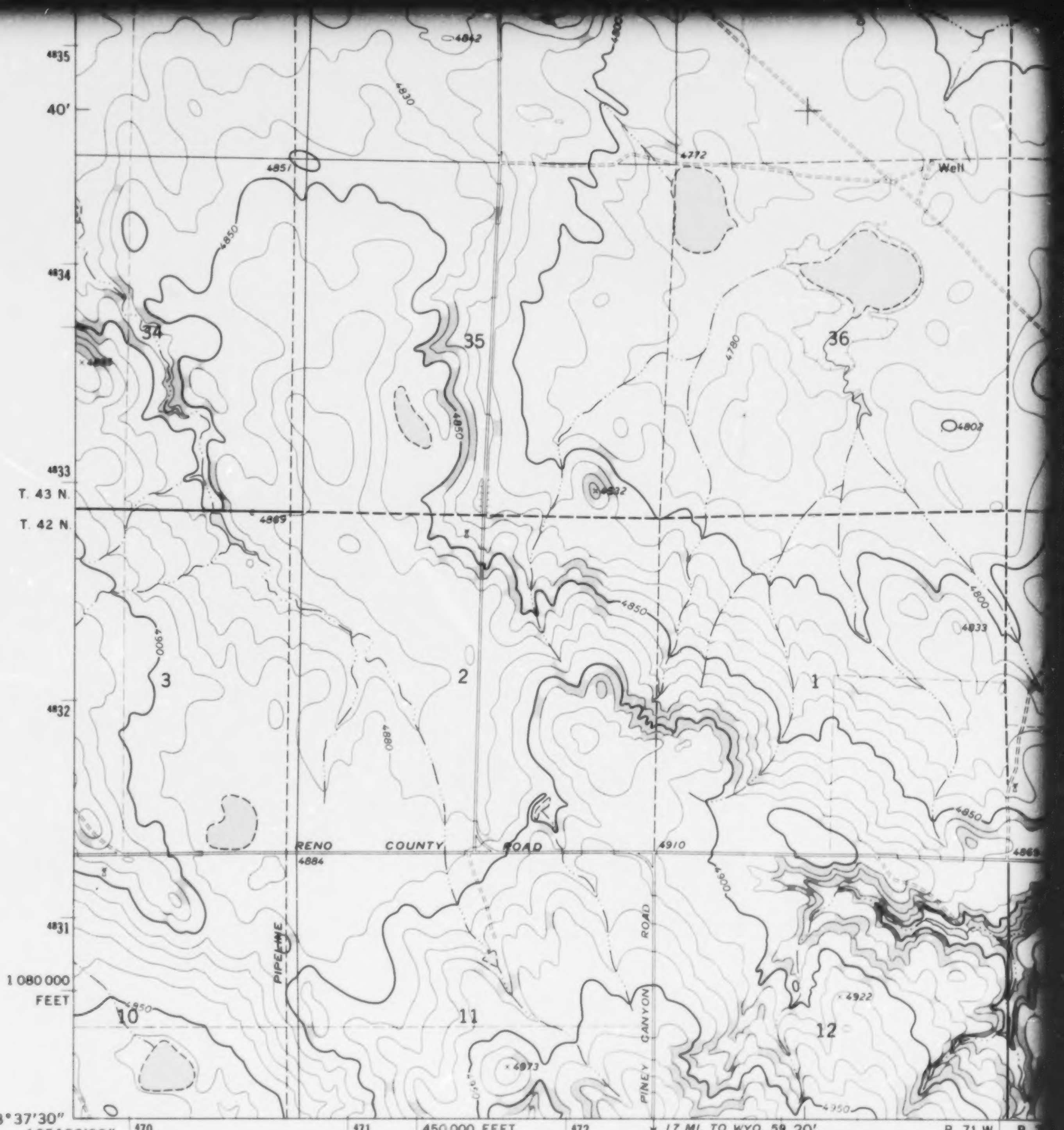
(OPEN A RANCH)




42'30"
4839
4838
4836
4835
40'
4834
4833
T. 43 N.
15
14
13
22
23
24
27
26
25
34
35
36
H I L
PIPELINE
(LITTLE THUNDER RESERVOIR)
Little
Well
4800
4801
4709
4750
4812
4796
4786
4780
4770
4797
4778
4773
4820
4815
4842
4830
4851
4850
4772
4802
4882


4709
4701
4700
4712
Drill Hole
Creek
Thunder
Well
17
18
4711
4680
4719
4710
4723
4750
19
20
21
Little
Thunder
4735
4720
4755
4766
4716
4725
4761
4773
30
Creek
Well
Reno Reservoir
28
4761
4742
4723
Well
Oil Well
32
31
33
4800
4812
4802
Trussler
4806
4774


Drill Hole
Creek
Well
17
4700
4711
4719
4710
4751
4839
4838
4680
4650
(PINEY CANYON NW)
20
21
4750
4765
4786
4836
4725
Creek
Well
Reno Reservoir
28
4835
40'
4762
4723
Oil Well
32
4834
Oil Well
33
34
Trussler
4800
4816
4774
4833
T. 43 N
T. 42 N
Draw



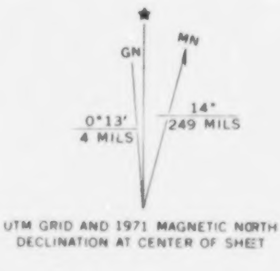
(TECKLA SW)

Mapped, edited, and published by the Geological Survey

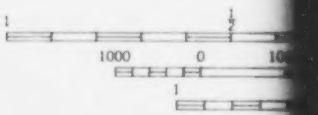
Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1971

Projection and 10,000-foot grid ticks: Wyoming coordinate system, east zone (transverse Mercator)
1000-meter Universal Transverse Mercator grid ticks, zone 13, 1927 North American datum

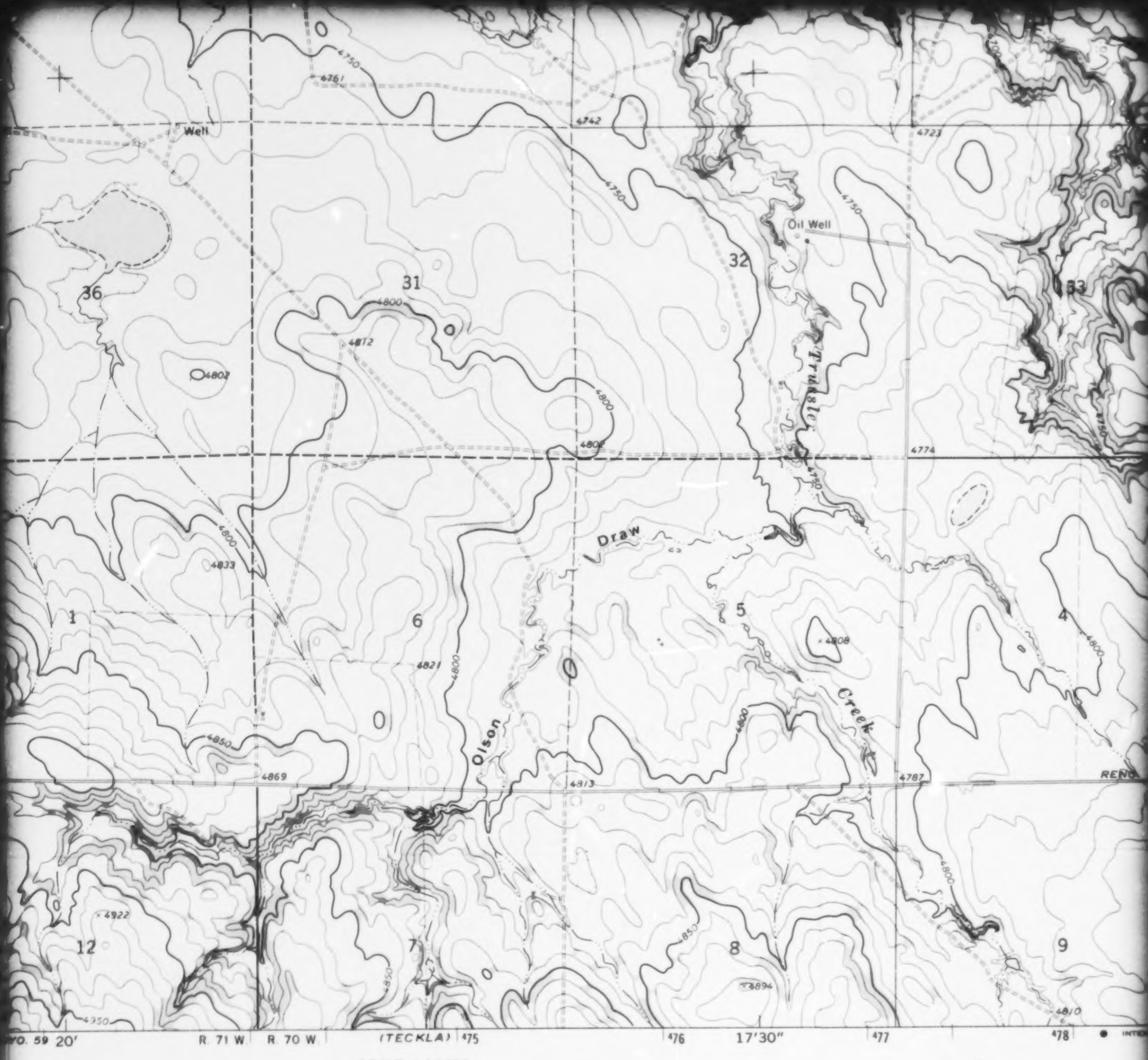


UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

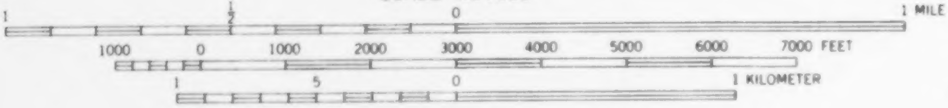


Note: The slope zones
photomechanical proc
of slope. Proximity of
false slope information
narrow drains and inci

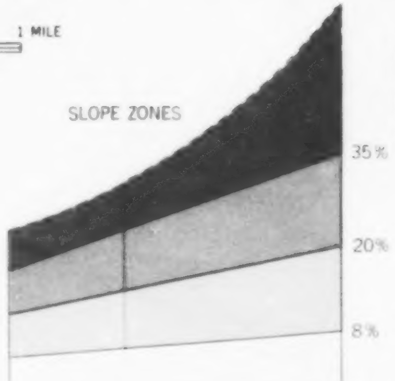
☆ GPO 781-902



SCALE 1:24 000



CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

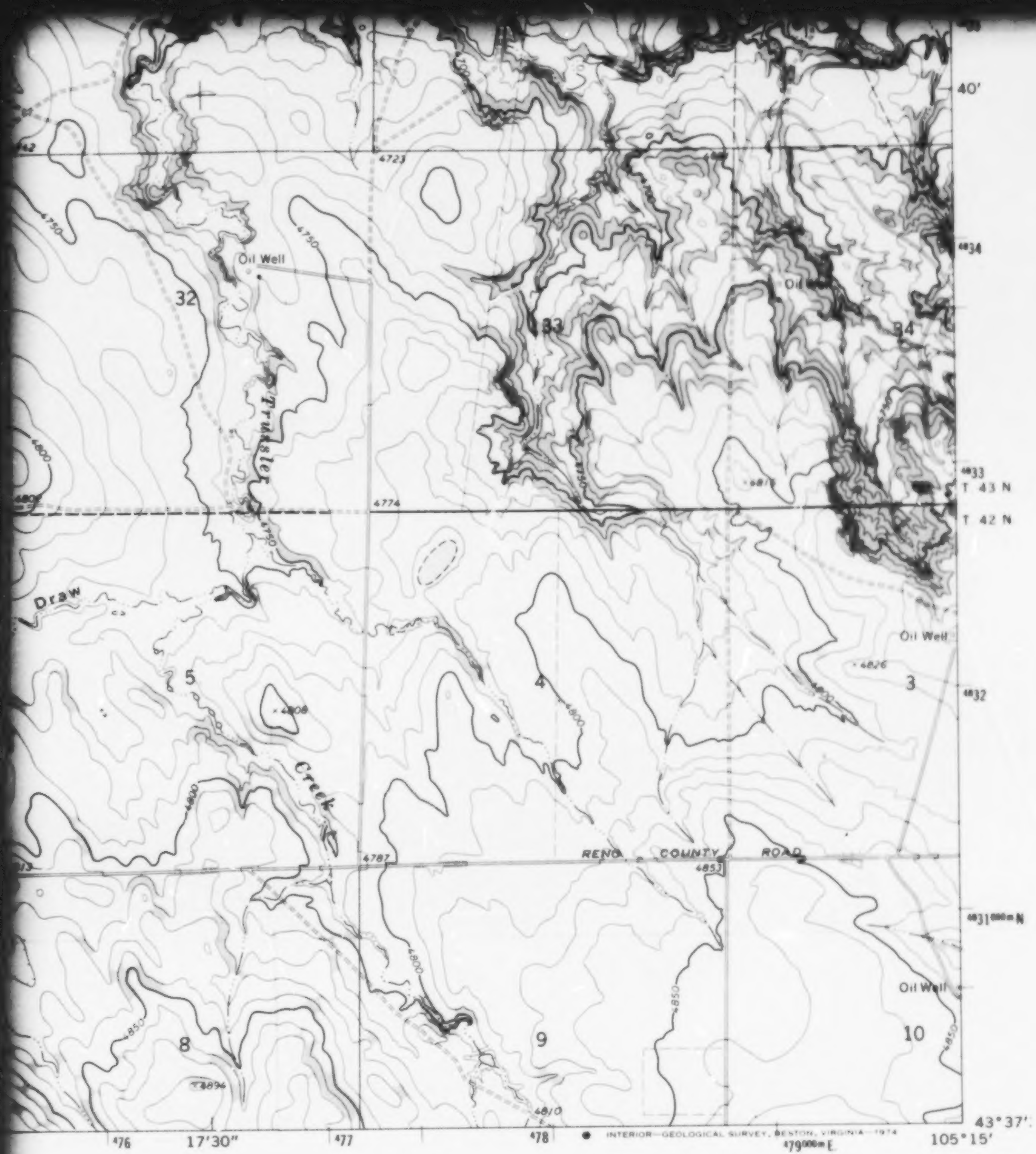


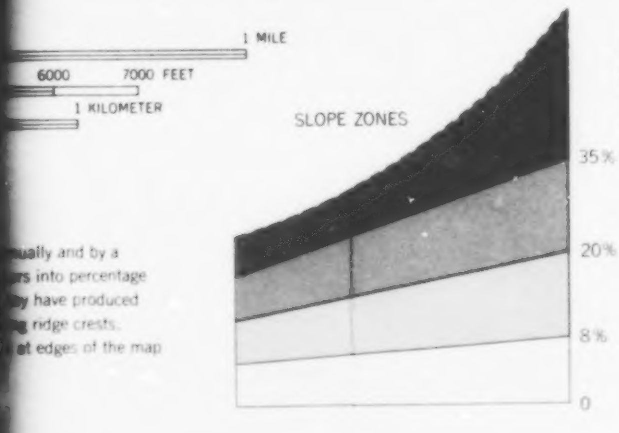
Primary highway, hard surface

Secondary highway, hard surface

Interstate

Note: The slope zones on this map are unedited. They were generated manually and by a photomechanical process which translates distance between adjacent contours into percentage of slope. Proximity of the same contour or absence of adjacent contours may have produced false slope information at small tops and depressions, on cuts and fills, along ridge crests, narrow drains and incised stream channels, along shores of open water, and at edges of the map.





ually and by a
rs into percentage
y have produced
g ridge crests.
at edges of the map

ROAD CLASSIFICATION

Primary highway, hard surface ▬▬	Light-duty road, hard or improved surface ═
Secondary highway, hard surface ▬ ▬ ▬	Unimproved road ┄┄┄
○ Interstate Route	○ U. S. Route ○ State Route

RENO RESERVOIR, WYO.

N4337.5—W10515/7.5

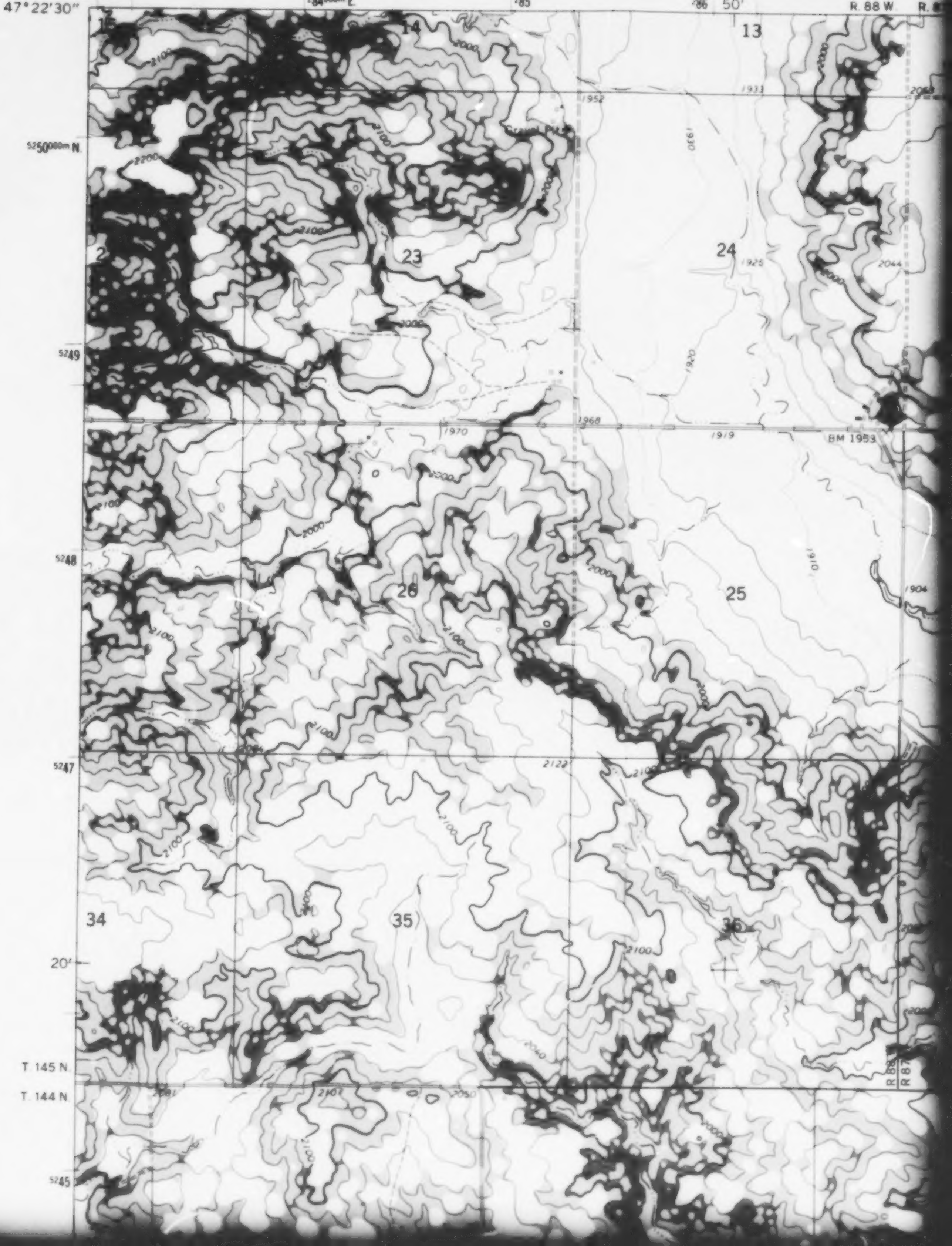
1971

AMS 4971 III NE—SERIES V874

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STA

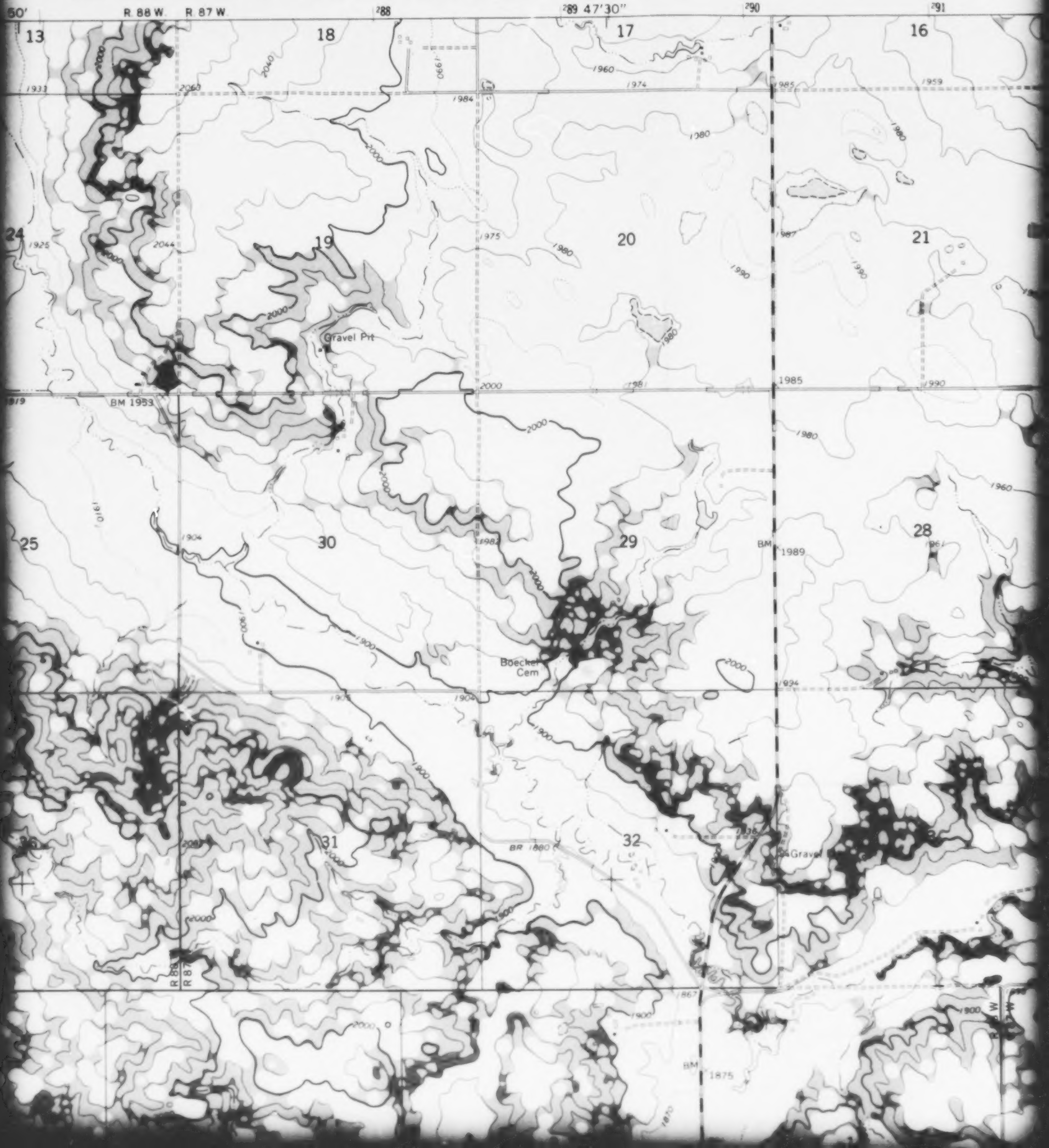
GOVERN
MILO W. HOISVE



STATE OF NORTH DAKOTA
WATER COMMISSION
GOVERNOR WILLIAM L. GUY, CHAIRMAN
MILO W. HOISVEEN, SECRETARY AND CHIEF ENGINEER

SLOPE MAP

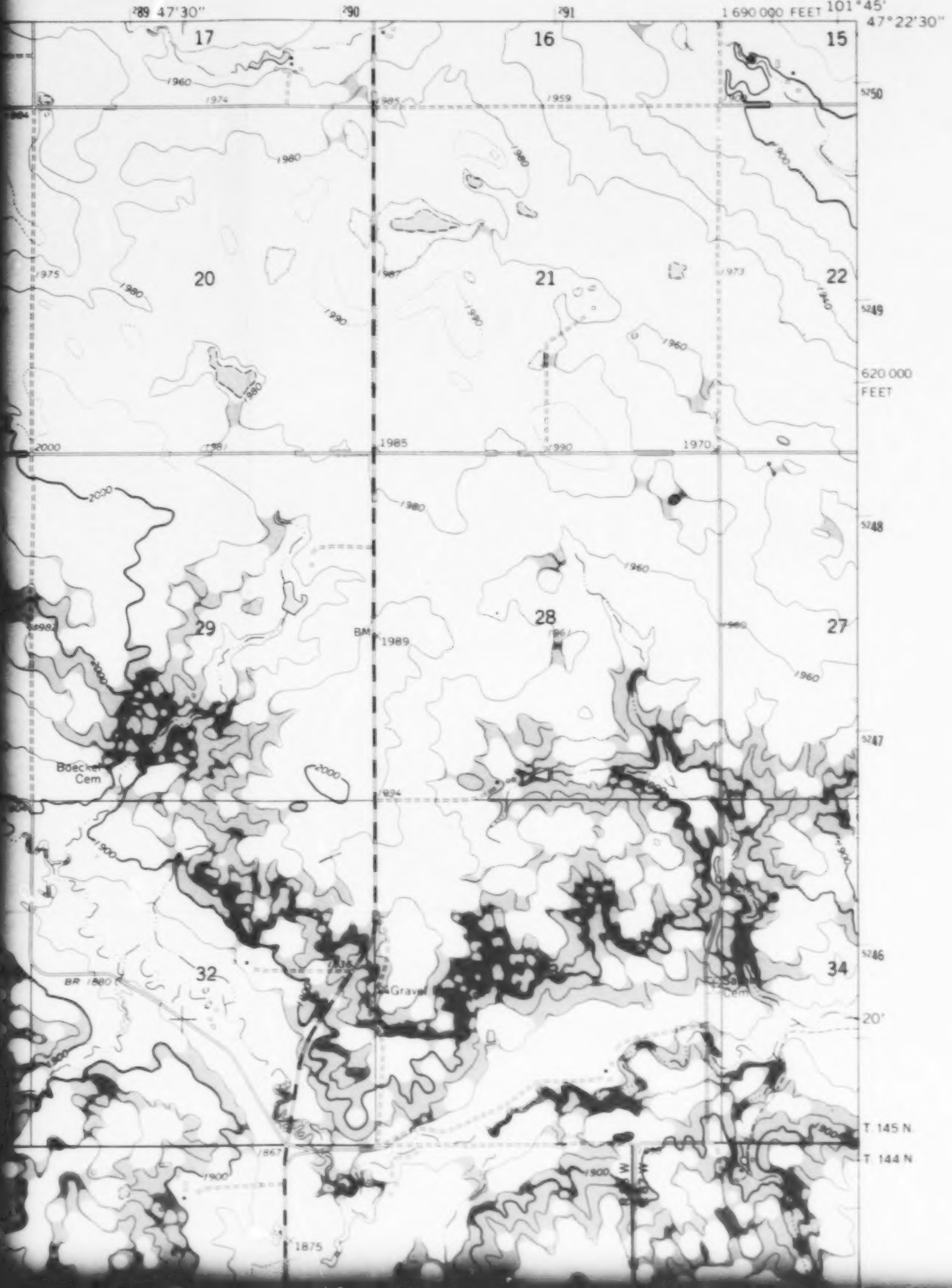
BEULAH QU
NORTH DAKOTA

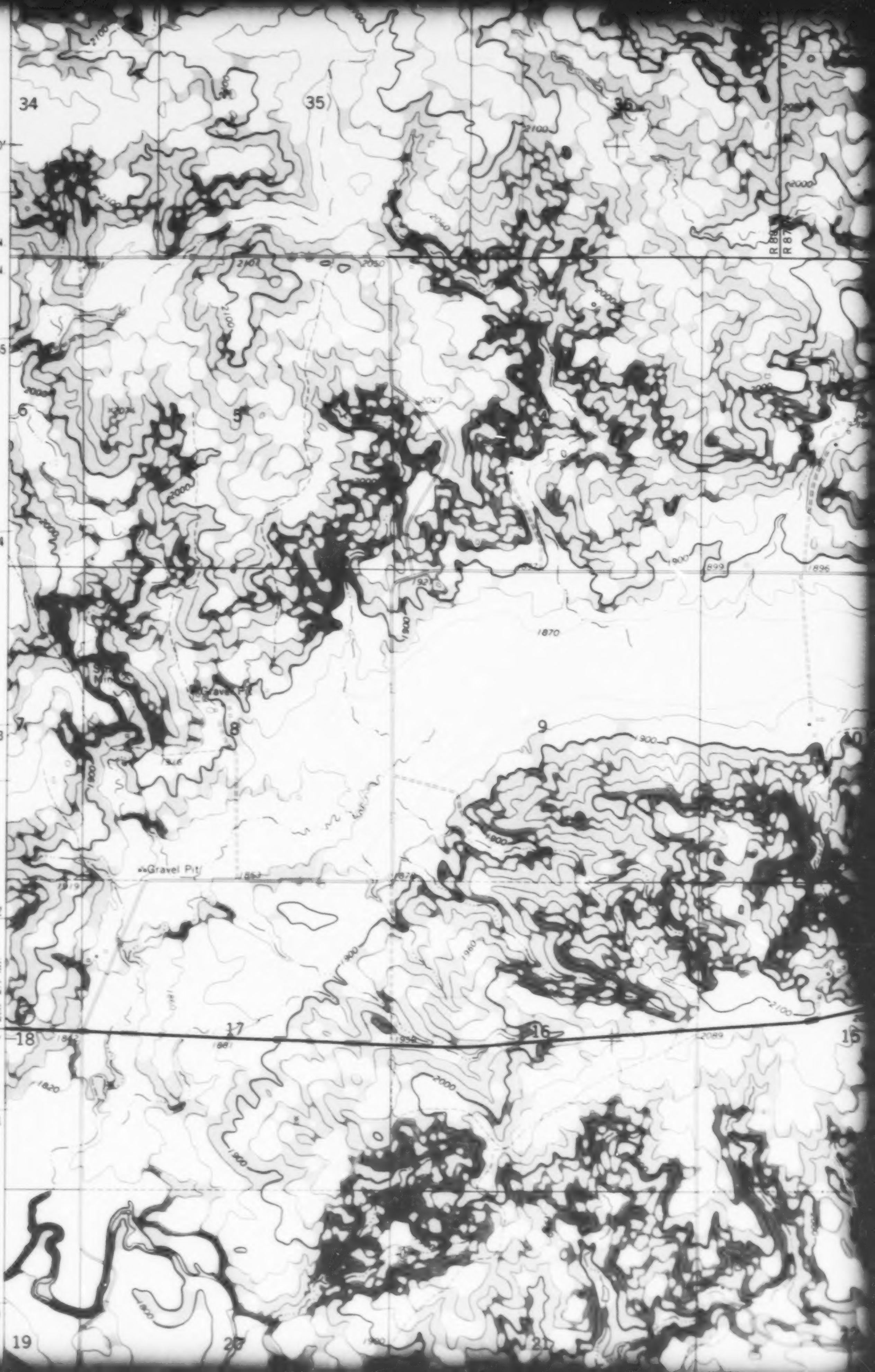


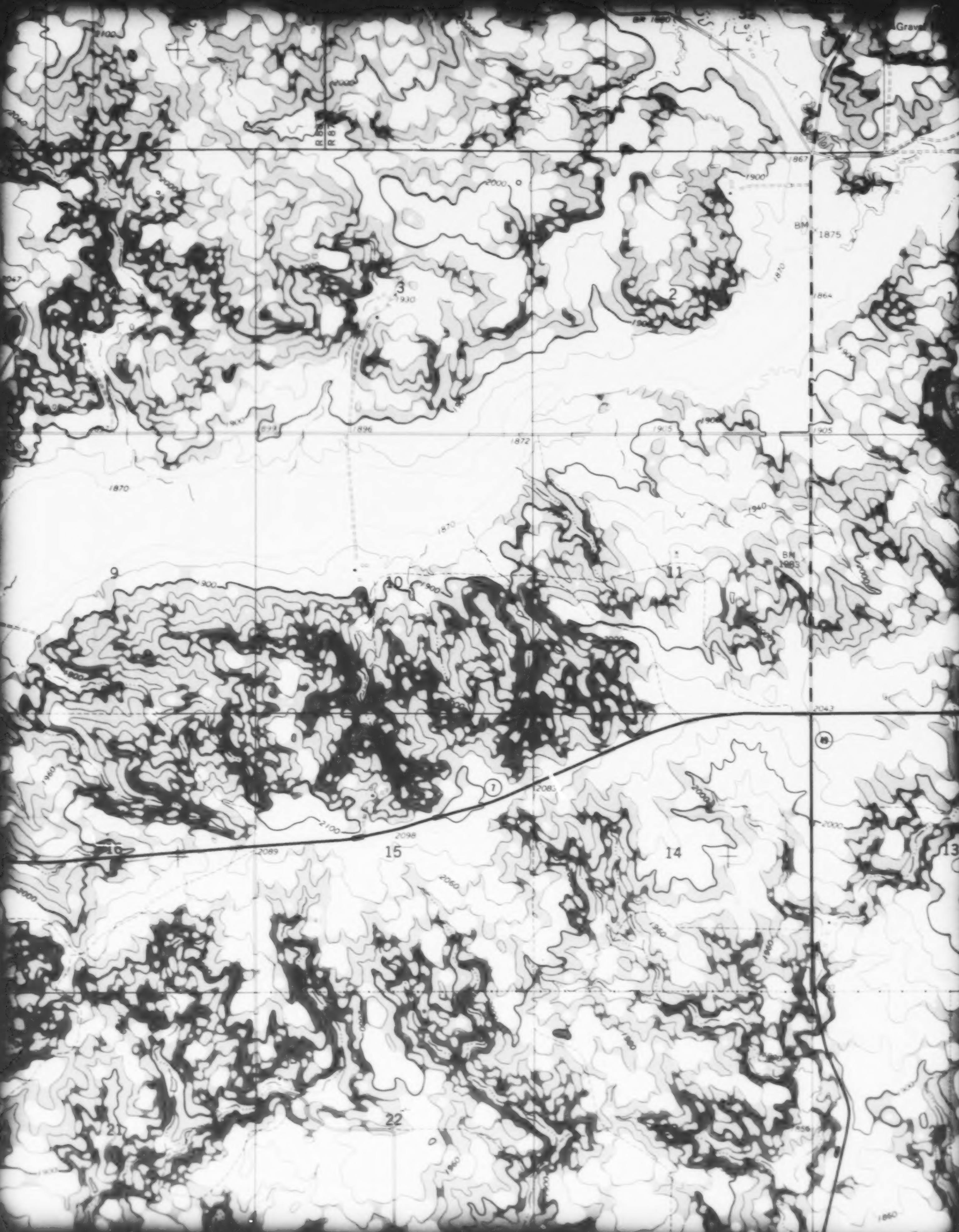
MAN
ENGINEER

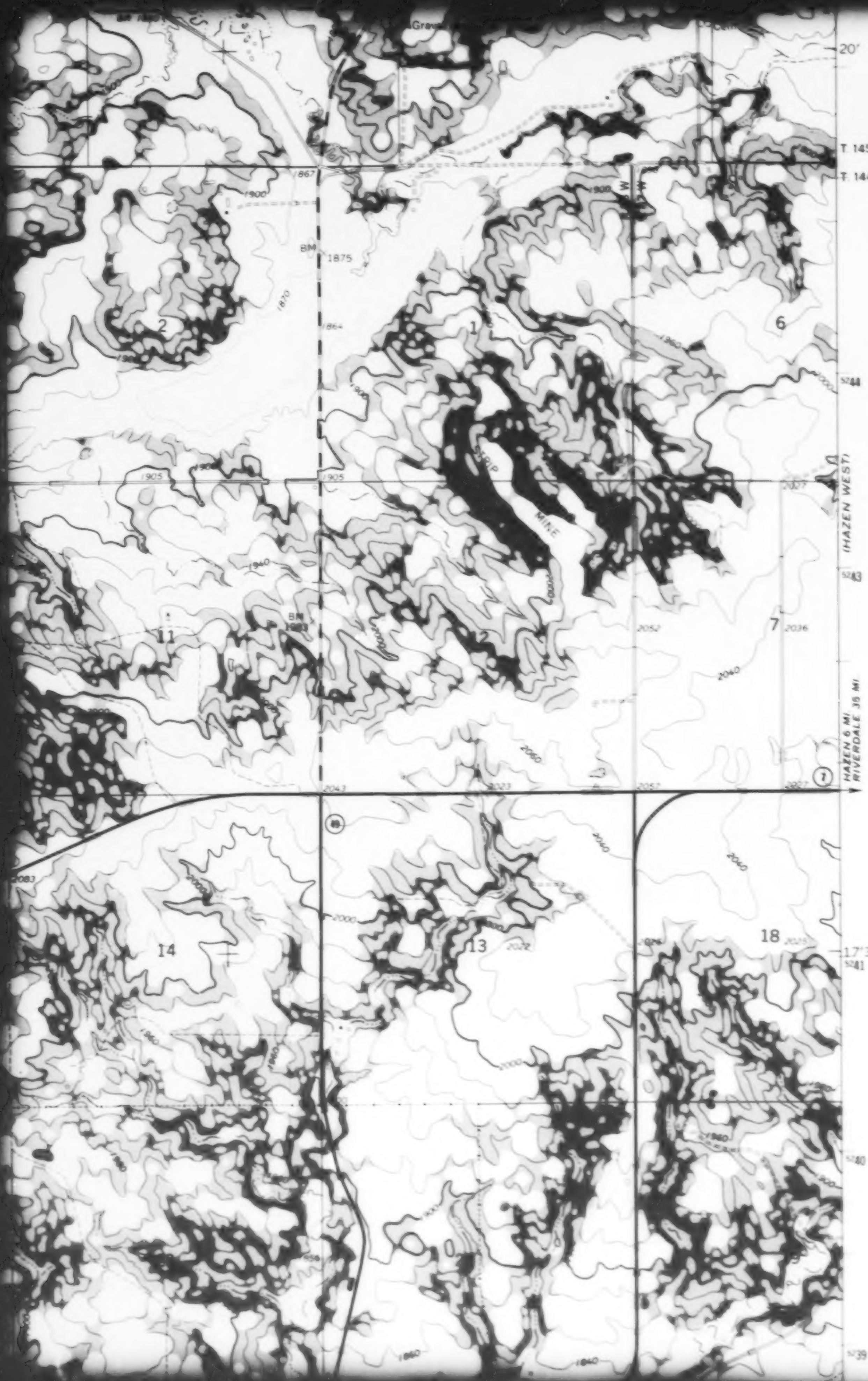
SLOPE MAP

BEULAH QUADRANGLE
NORTH DAKOTA – MERCER CO.

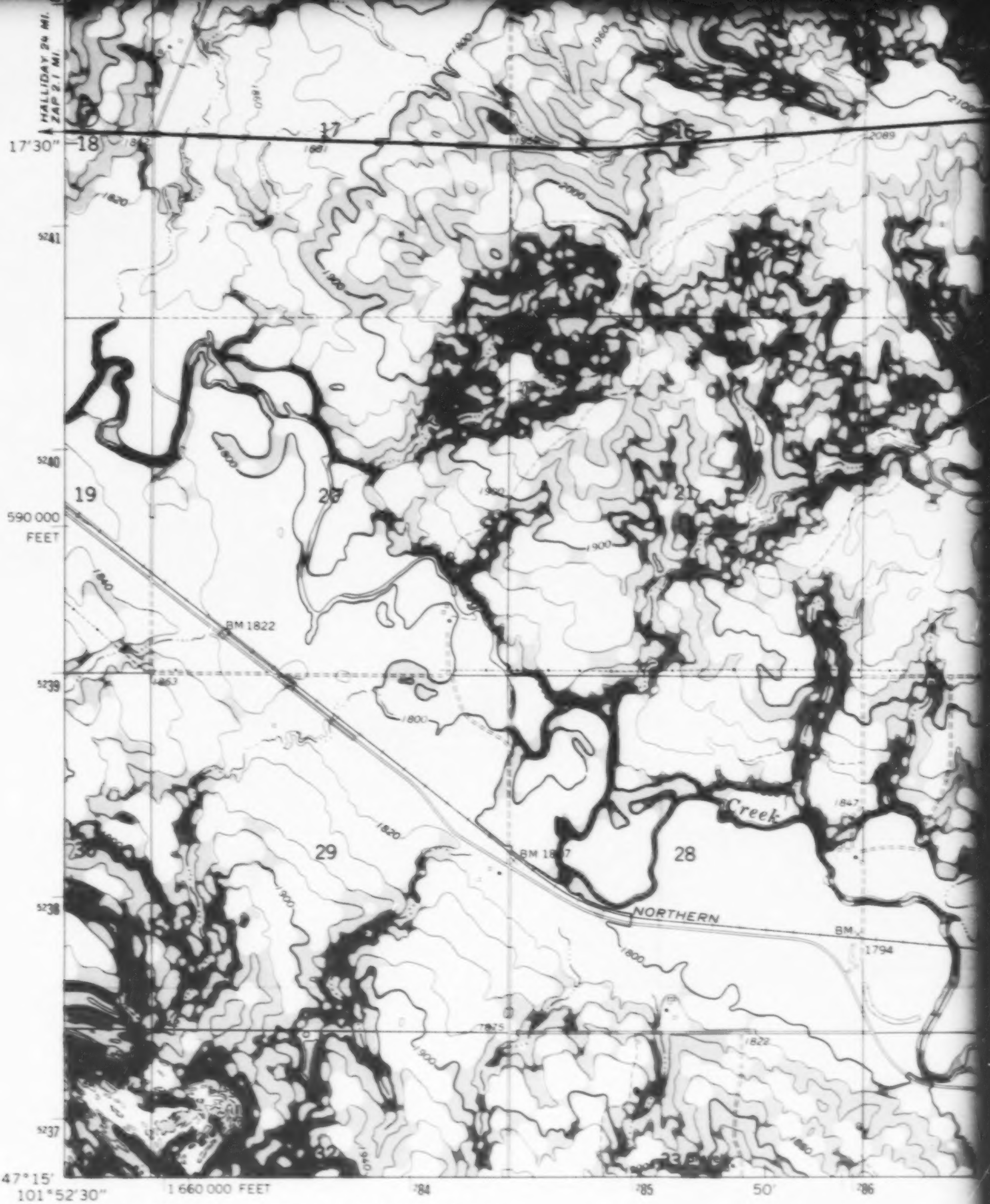



34
35
36
20'
T. 145 N.
T. 144 N.
5245
6
5
5244
5243
7
8
9
10
Gravel Pit
Gravel Pit
5242
HALLIDAY 24 MI.
ZAP 2.1 MI.
17'30"
18
17
16
15
5241
5240
19
20
21
2100
2000
1900
1870
1899
1896
1820
2089


Gravel
2100
2040
2047
2000
1930
3
2
1
1900
1867
1875
BM
1864
1870
1896
1872
1905
1940
9
10
11
BM
1983
1900
1960
2043
7
2083
2100
2098
2089
15
14
13
16
2060
1960
21
22
1860



20'
T. 145 N.
T. 144 N.
Gravel
1867
1900
BM
1875
1870
1864
1900
2
1
6
5744
STRIP
MINE
1905
1905
1940
2027
(HAZEN WEST)
5743
BM
11
12
7
2052
2036
2040
2060
HAZEN 6 MI
RIVERDALE 35 MI
2043
2023
2057
2027
2083
2040
2040
2000
14
13
2022
18
2026
2025
17'30"
5741
1960
1960
5740
1860
1840
5739



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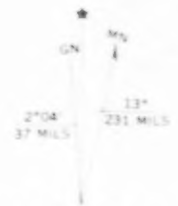
Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1967. Field checked 1968

Polyconic projection. 1927 North American datum
10,000-foot grid based on North Dakota coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks,
zone 14.

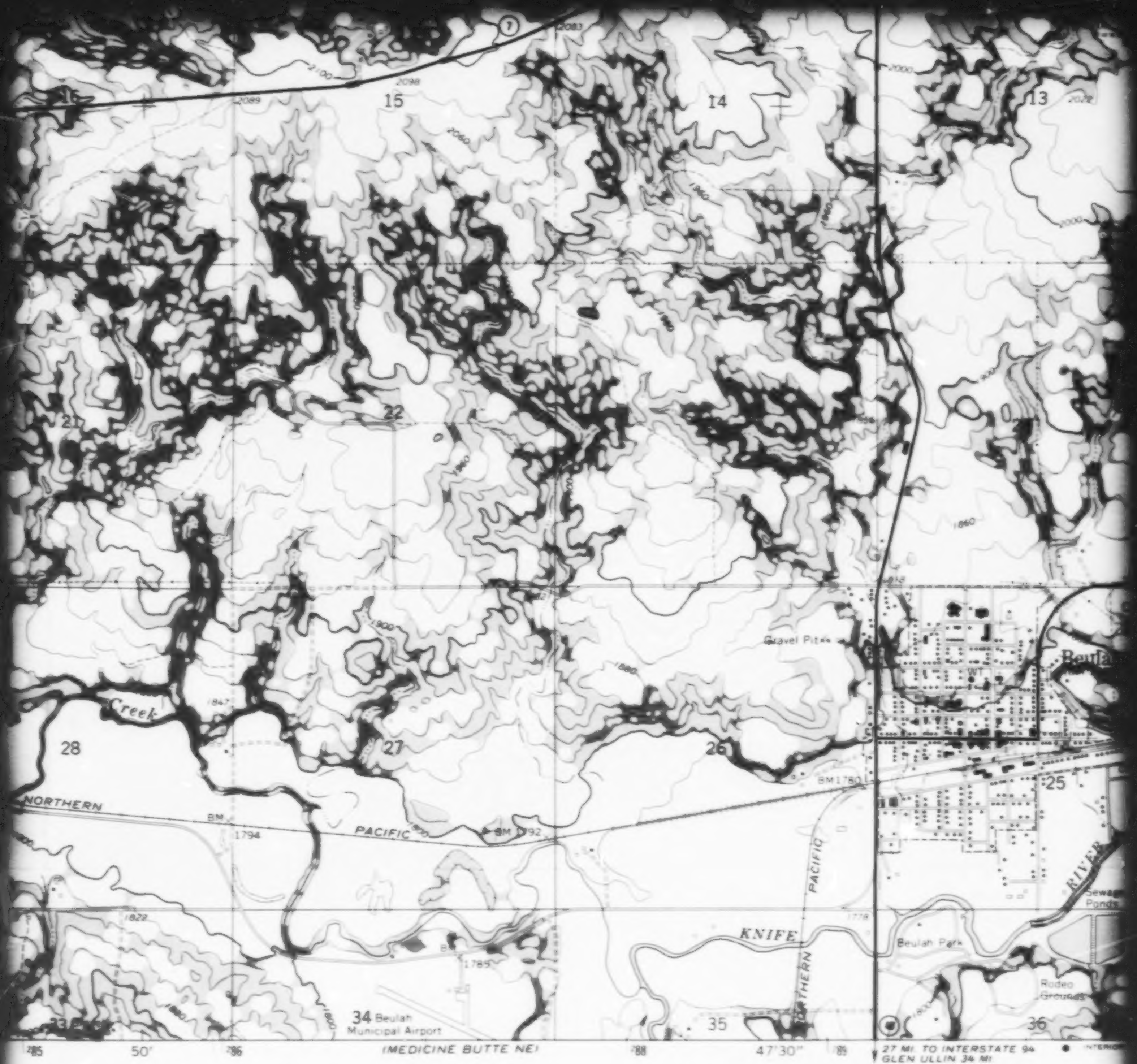


UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

DOTT

Note: The slope zone
photomechanical proc
of slope. Proximity o
false slope informatio
narrow drains and inc

☆ GPO 781-902



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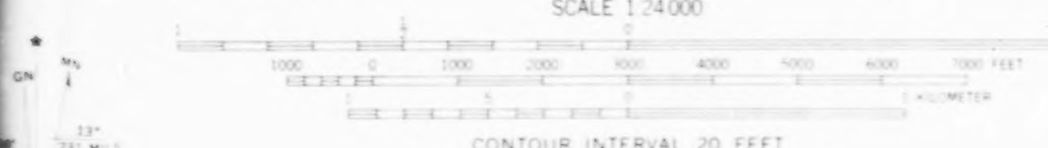
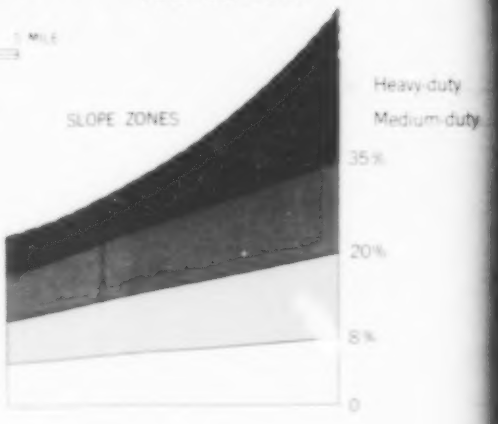
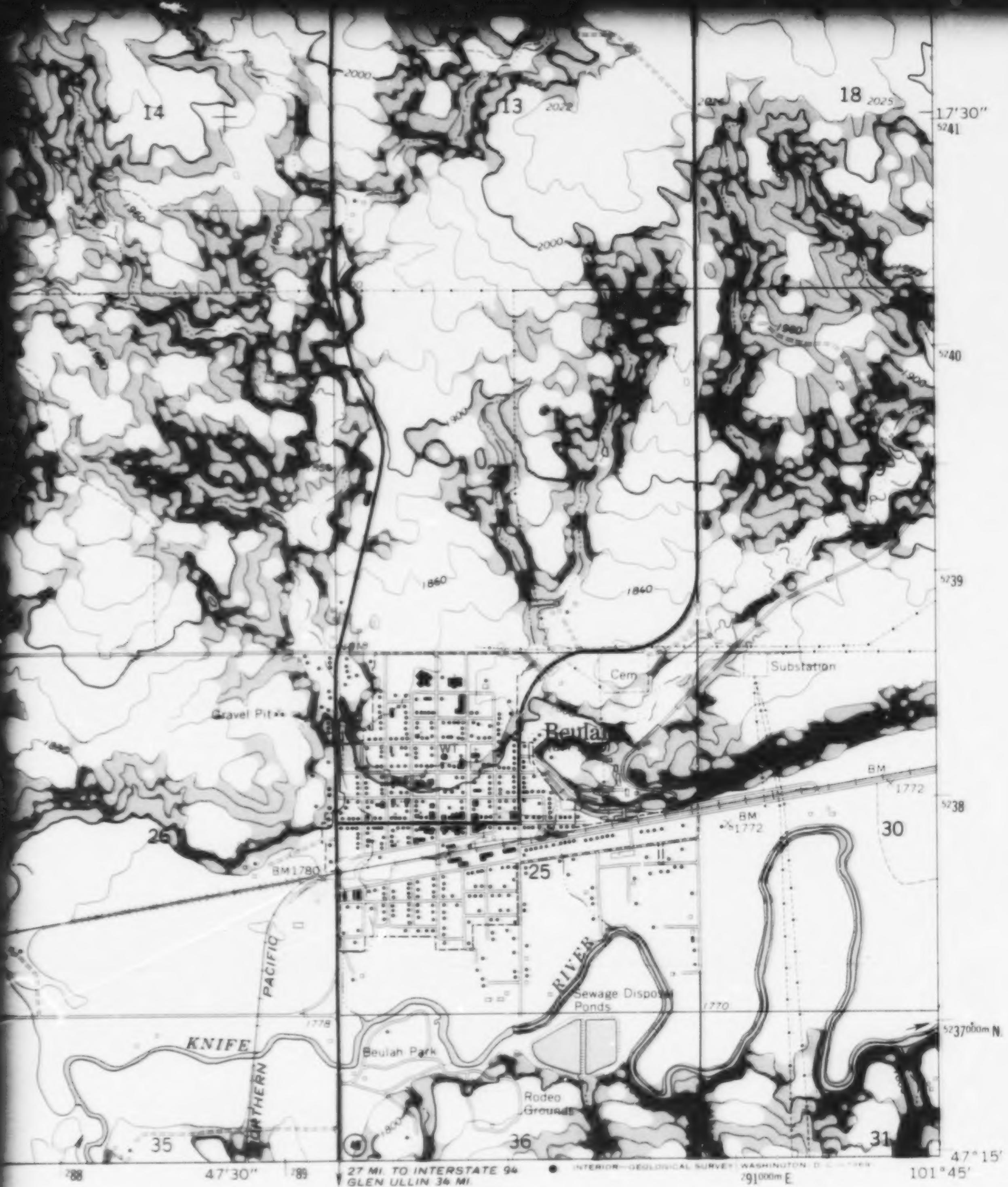


CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Note: The slope zones on this map are unedited. They were generated manually and by a photomechanical process which translates distance between adjacent contours into percentage of slope. Proximity of the same contour or absence of adjacent contours may have produced false slope information at small tops and depressions, on cuts and fills, along ridge crests, narrow drains and incised stream channels, along shores of open water, and at edges of the map.





1 MILE

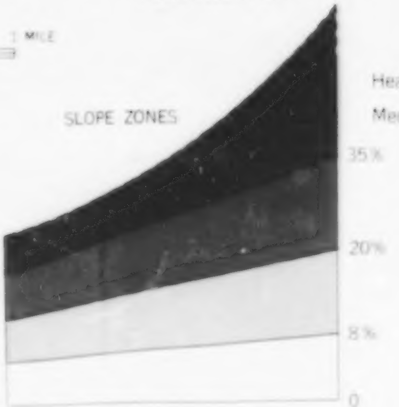
000 6000 7000 FEET

1 KILOMETER

TOURS

ted manually and by a
contours into percentage
ours may have produced
s, along ridge crests,
r, and at edges of the map

SLOPE ZONES



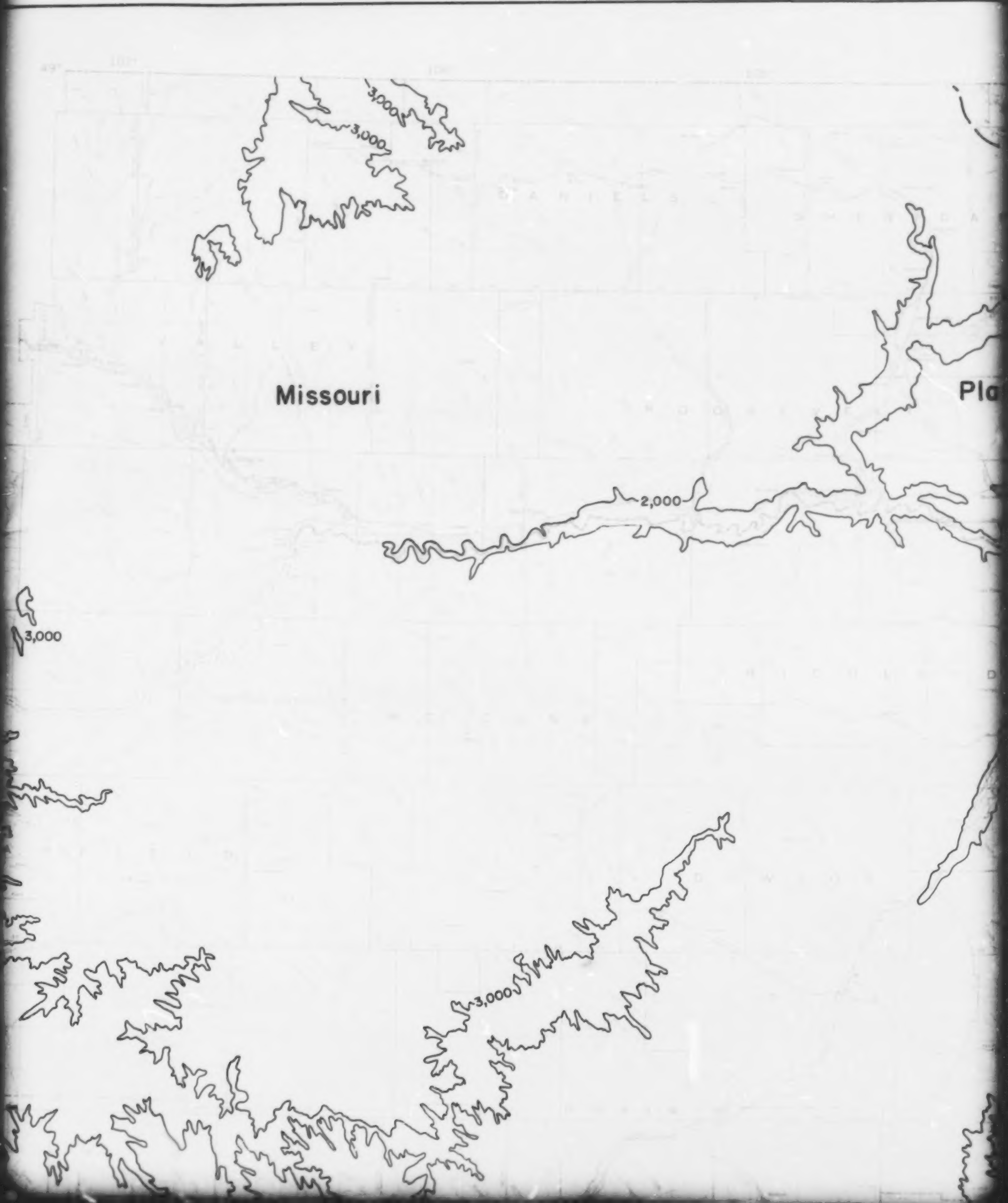
ROAD CLASSIFICATION

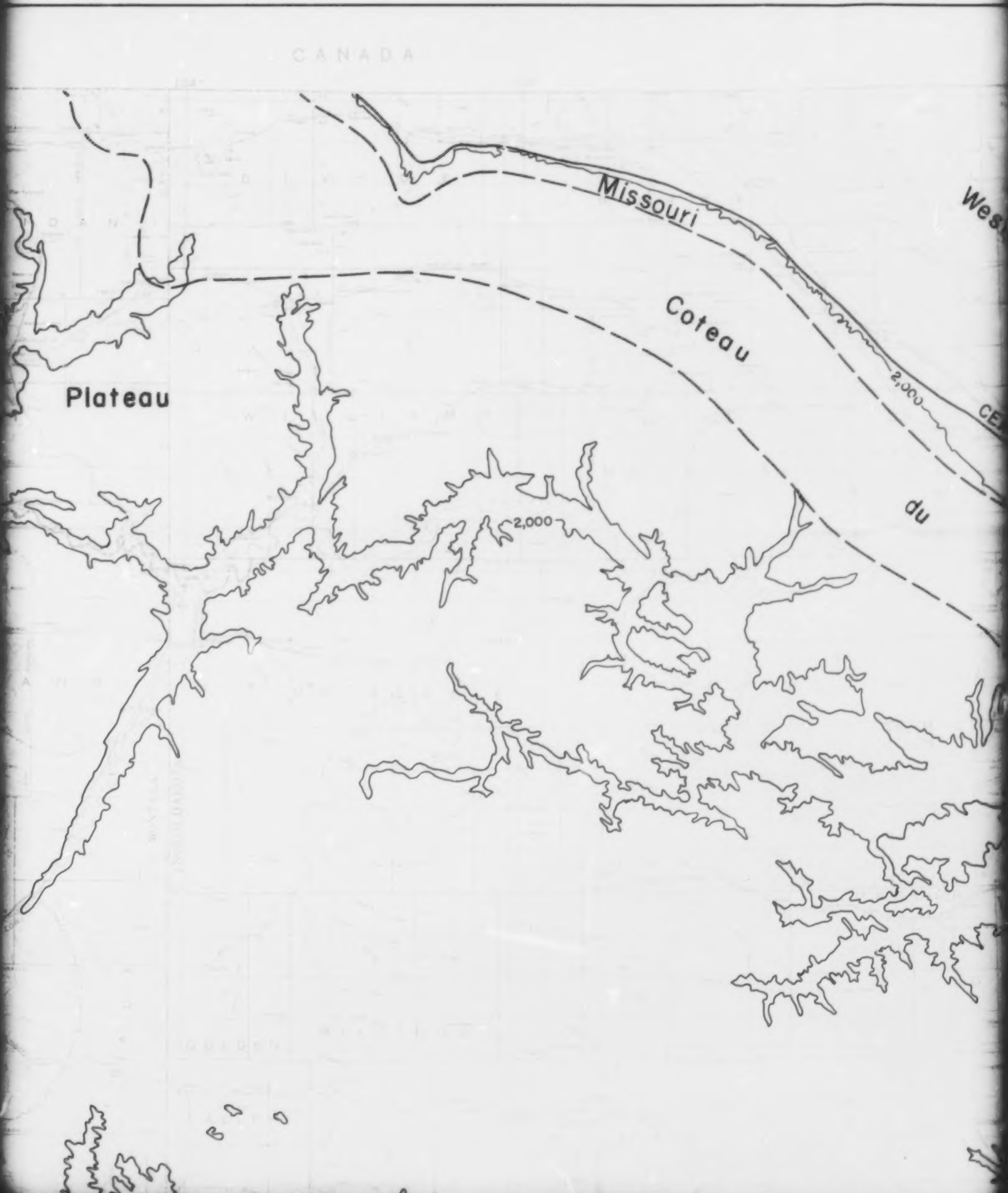
Heavy-duty ━━━ Light-duty ───
Medium-duty ━ ━ ━ Unimproved dirt - - - -
◯ State Route

BEULAH, N. DAK.
N4715—W10145/7.5

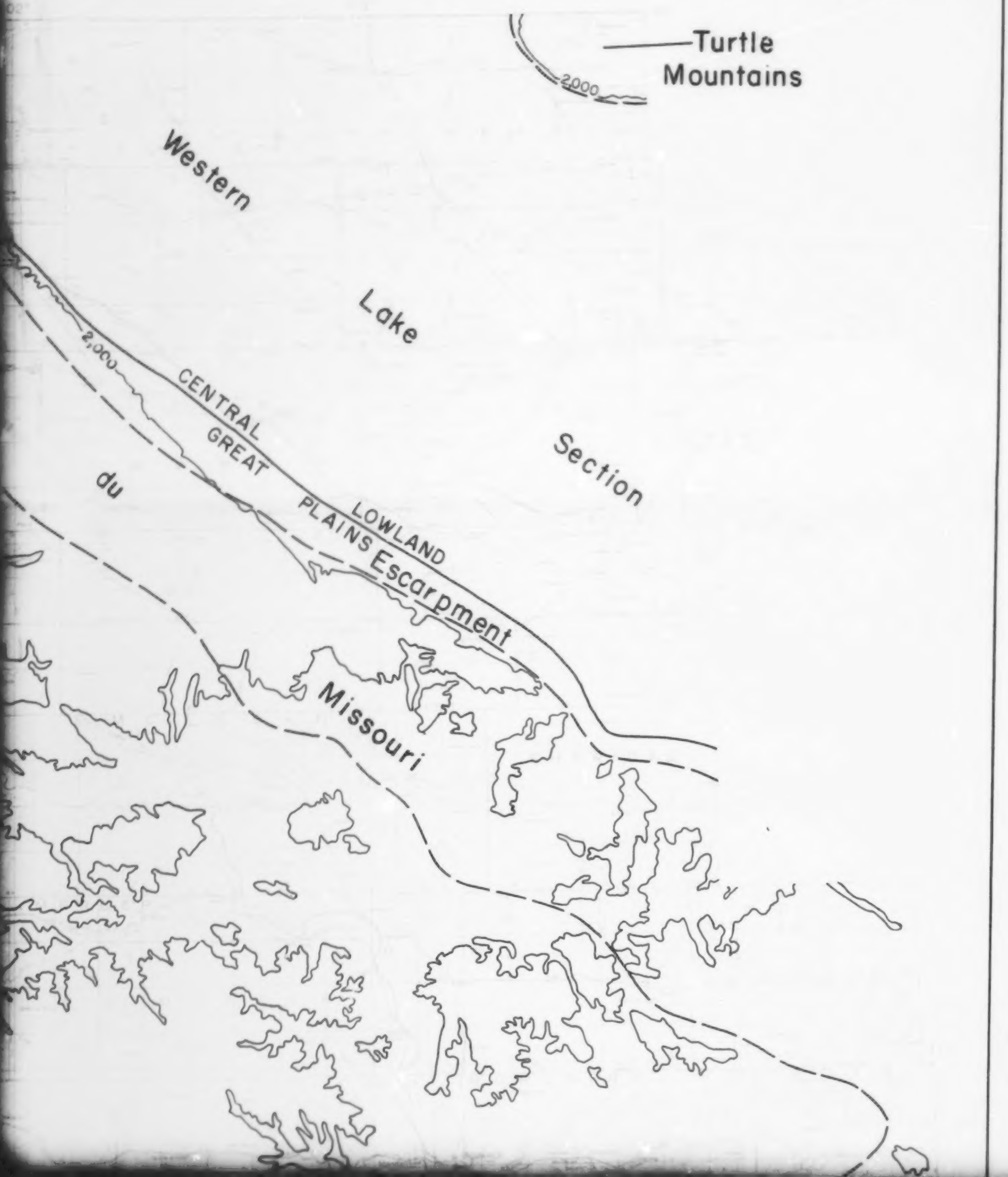
1968

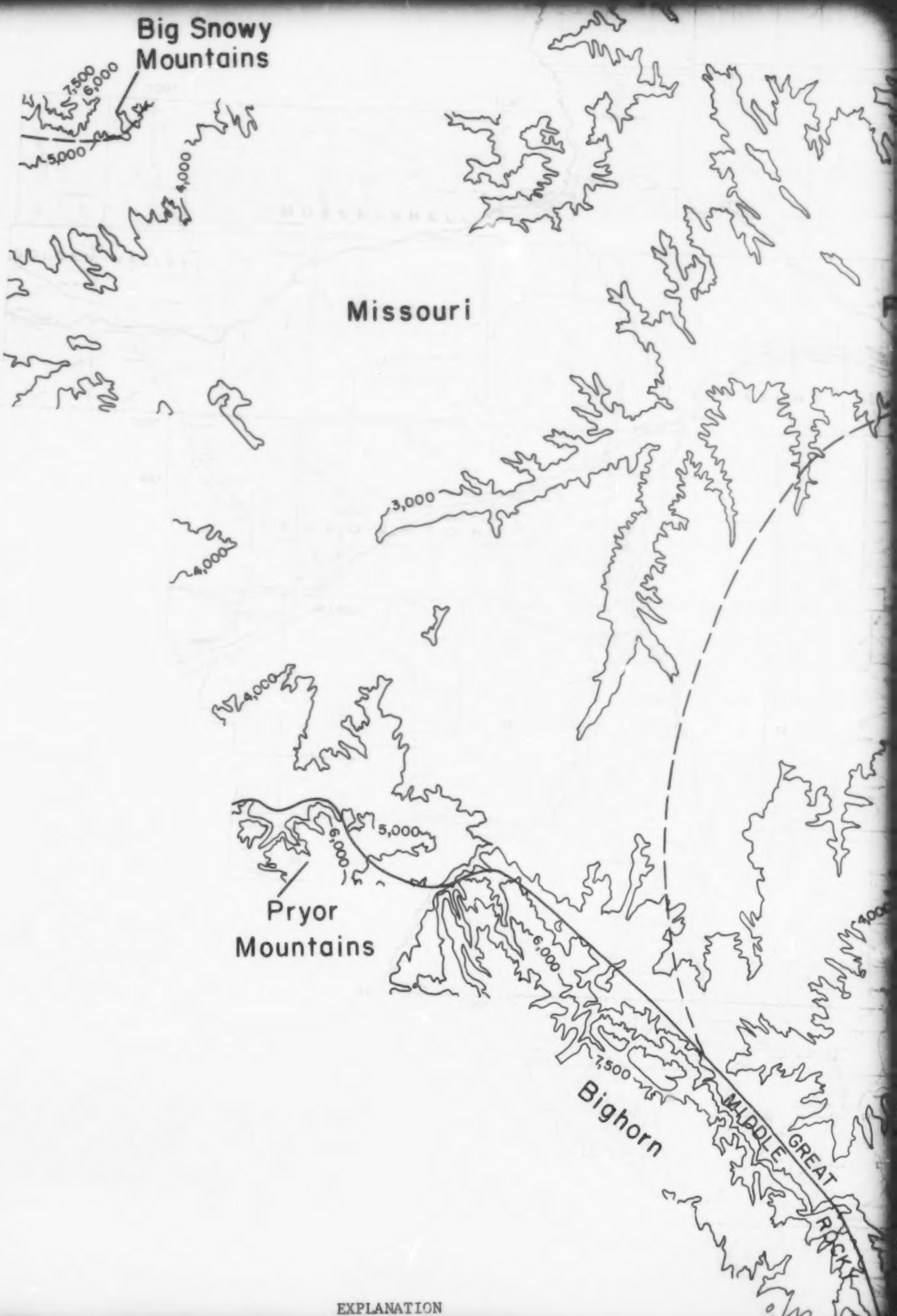
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY


3,000
3,000
DANIELS
SHERIDAN
VALLEY
Missouri
Pla
ROOSEVELT
2,000
3,000
RICHLAND
McCONE
DAWSON
3,000

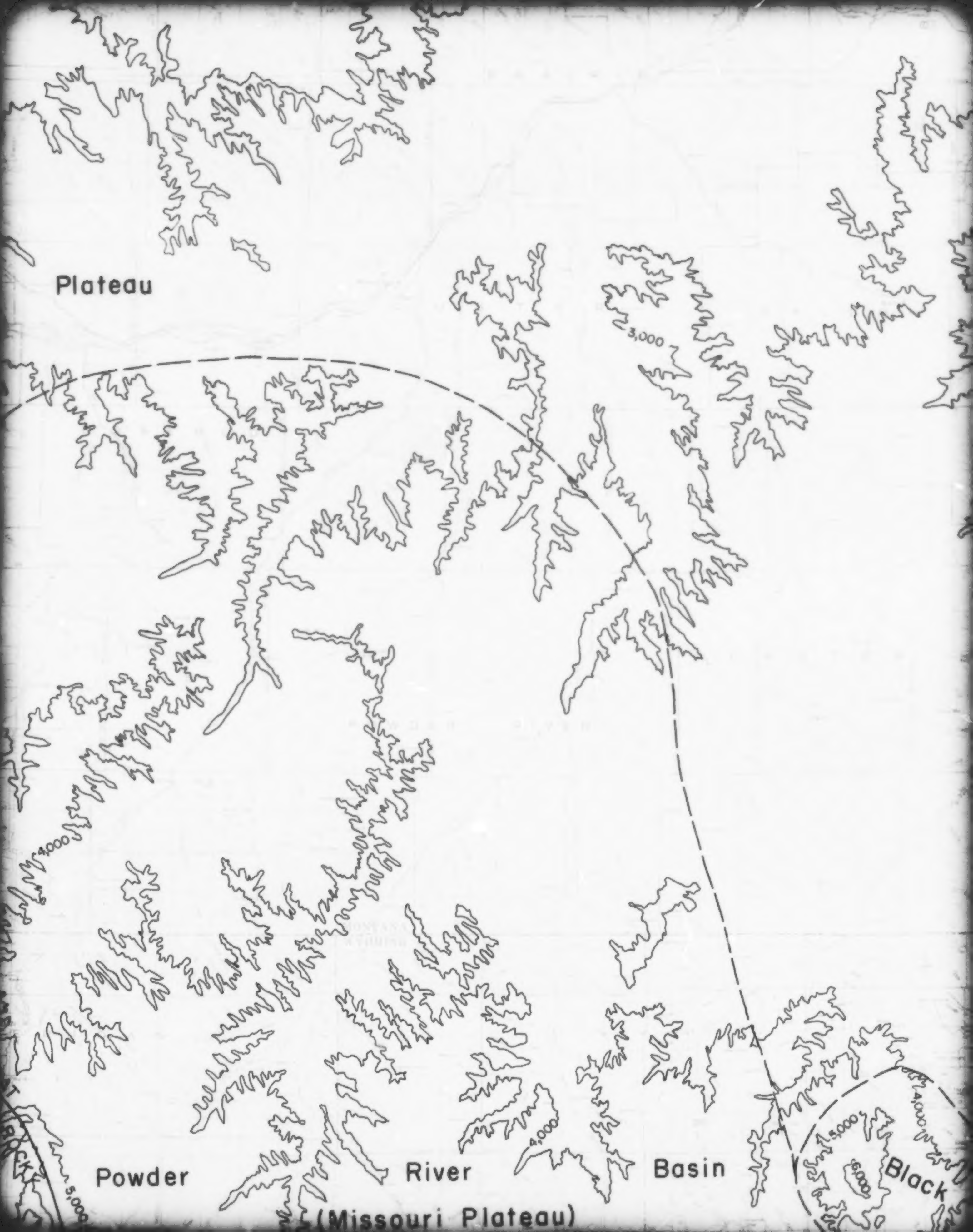

CANADA
Missouri
Coteau
du
Plateau
2,000
2,000
Wes
CE

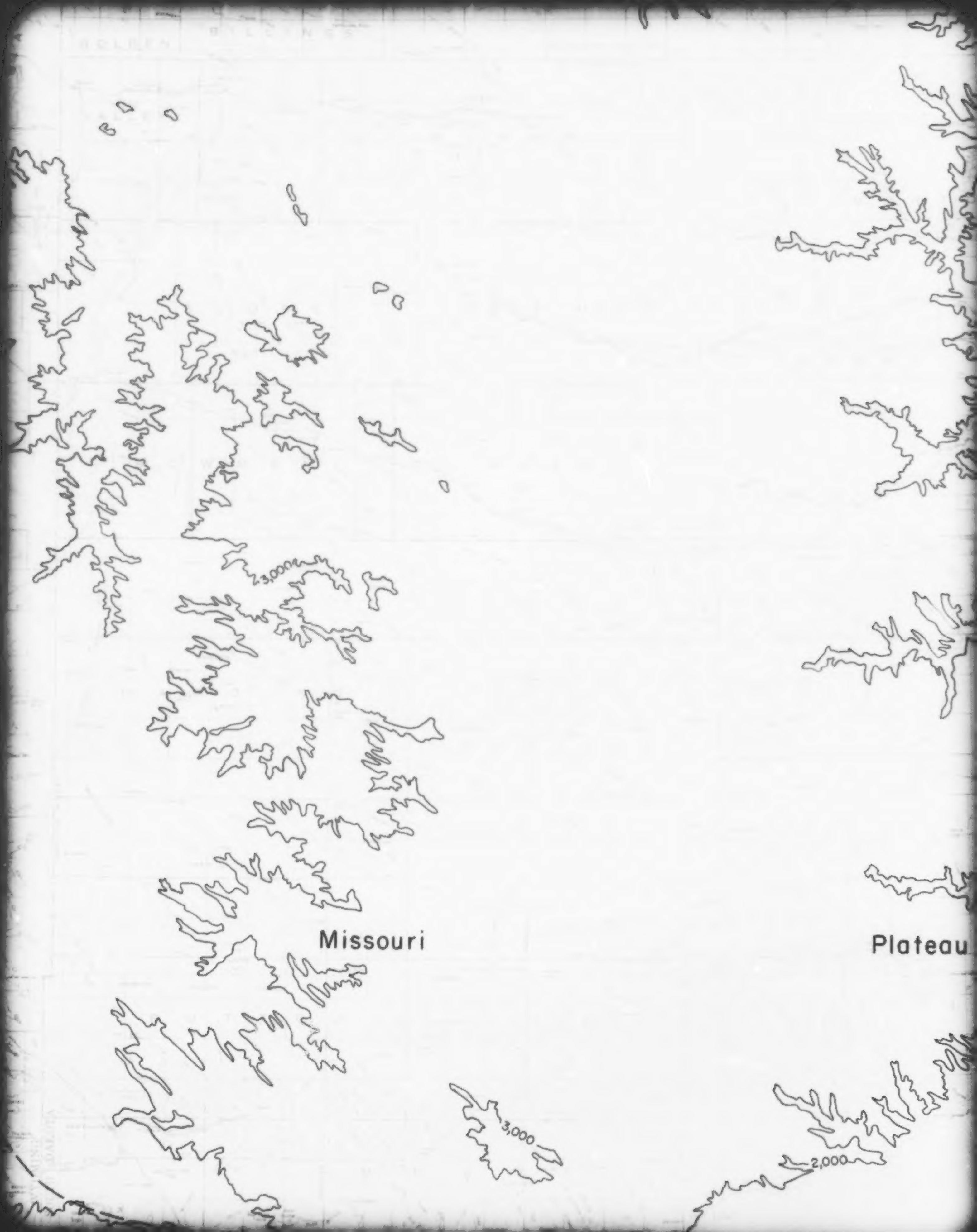
OPEN-FILE REPORT
74-50

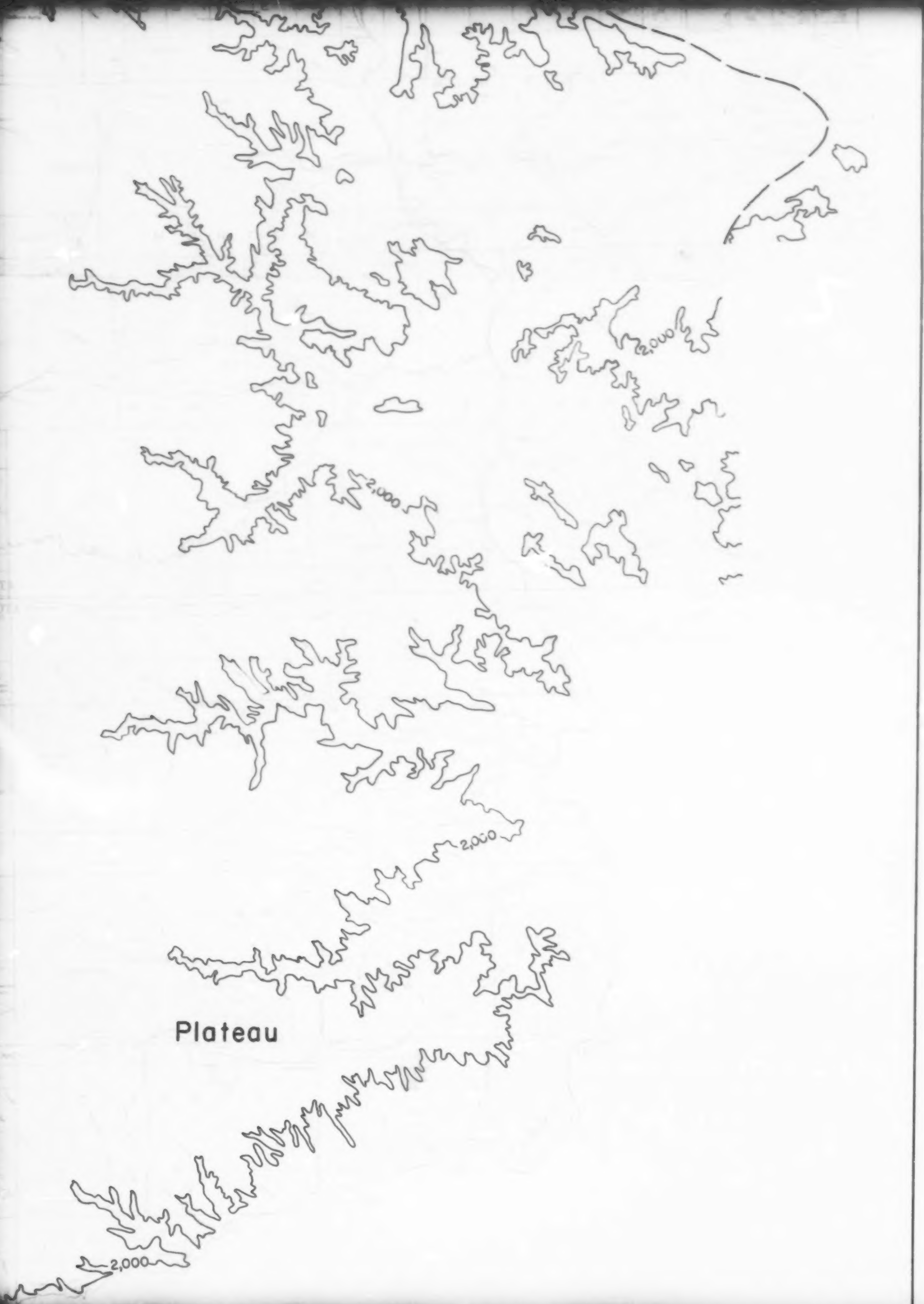




EXPLANATION


Plateau
3,000
4,000
4,000
5,000
ROCKY
Powder
River
Basin
(Missouri Plateau)
Black
4,000
5,000
6,000


BILLINGS
3,000
Missouri
Plateau
3,000
2,000

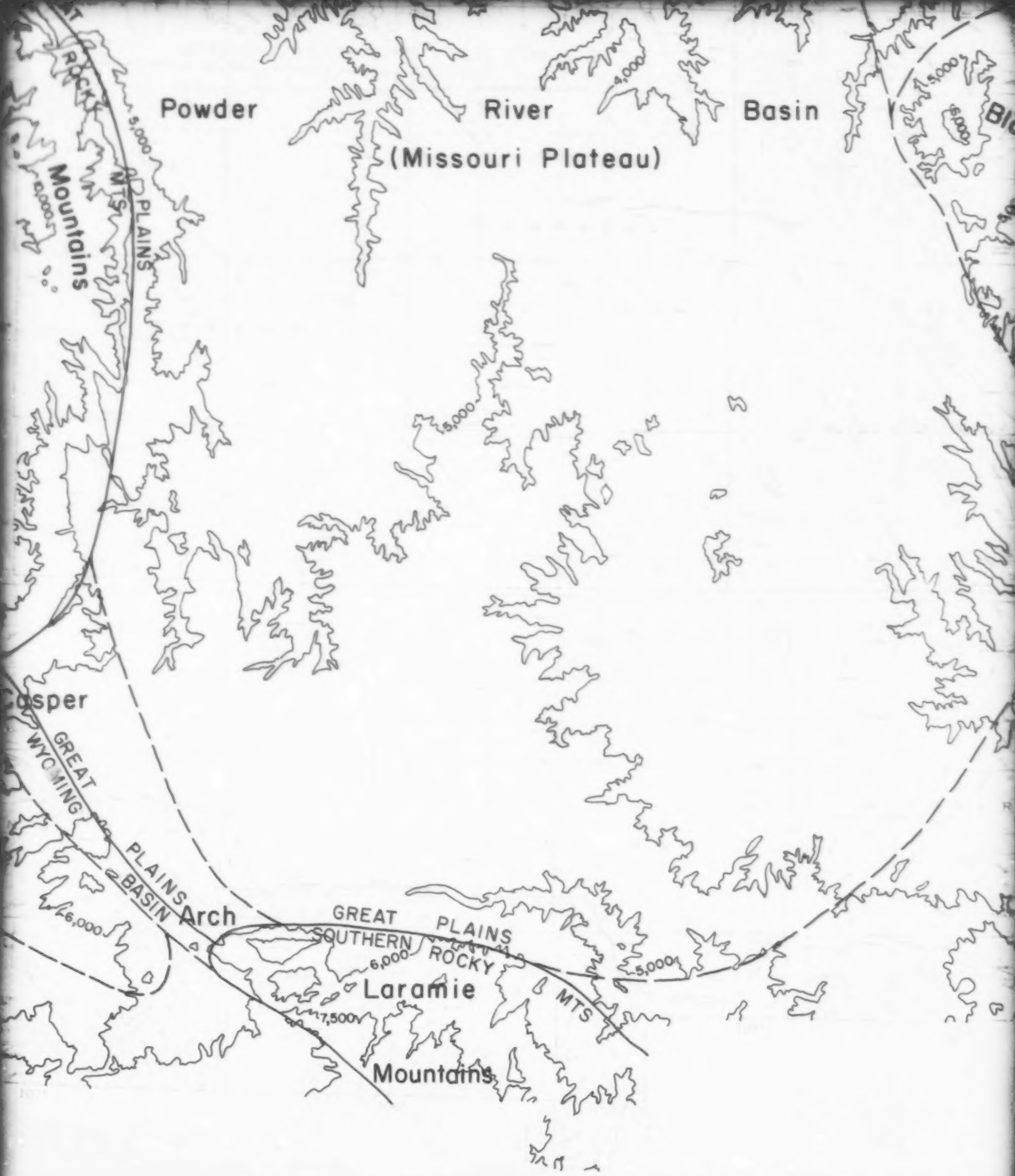

2,000
2,000
2,000
Plateau
2,000

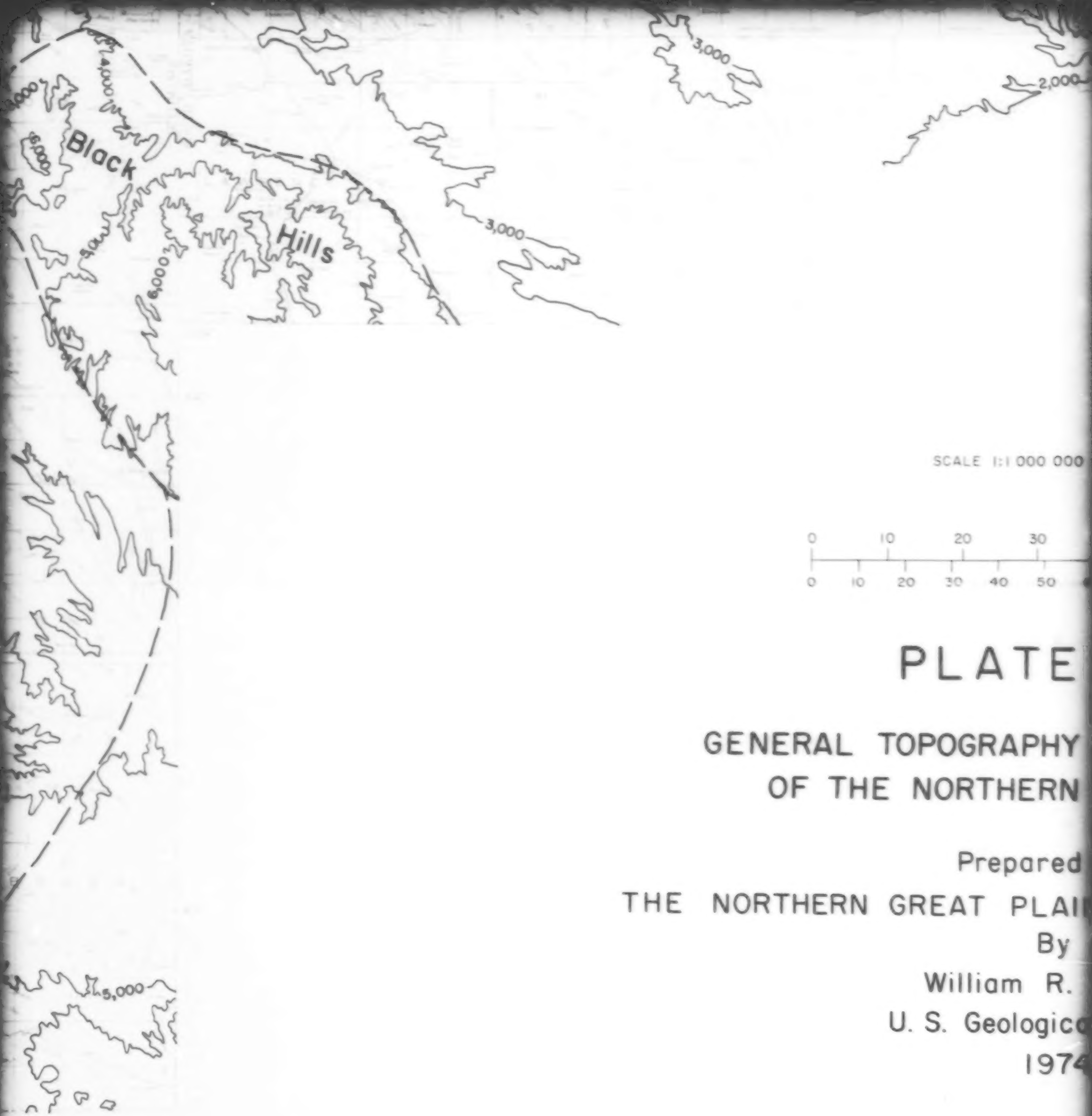
EXPLANATION

Boundary between major physiographic provinces

Boundary between physical features within physiographic provinces

Base from U.S. Geological Survey
State base maps


Powder River Basin
(Missouri Plateau)
4,000
5,000
6,000
ROCKY MTS
PLAINS
Mountains
5,000
Casper
GREAT PLAINS
WYOMING BASIN
6,000
Arch
GREAT PLAINS
SOUTHERN ROCKY MTS
6,000
5,000
Laramie
7,500
Mountains



PLATE

GENERAL TOPOGRAPHY
OF THE NORTHERN

Prepared
THE NORTHERN GREAT PLAI
By
William R.
U. S. Geologic
1974

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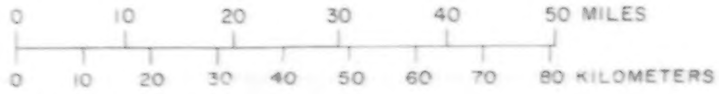

PLATE A-1

GENERAL TOPOGRAPHY AND PHYSIOGRAPHY OF THE NORTHERN GREAT PLAINS

Prepared for
E NORTHERN GREAT PLAINS RESOURCES PROGRAM
By
William R. Keefer
U. S. Geological Survey
1974

U.S. Geological Survey
OPEN FILE REPORT
This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

DEPARTMENT OF THE INTERIOR
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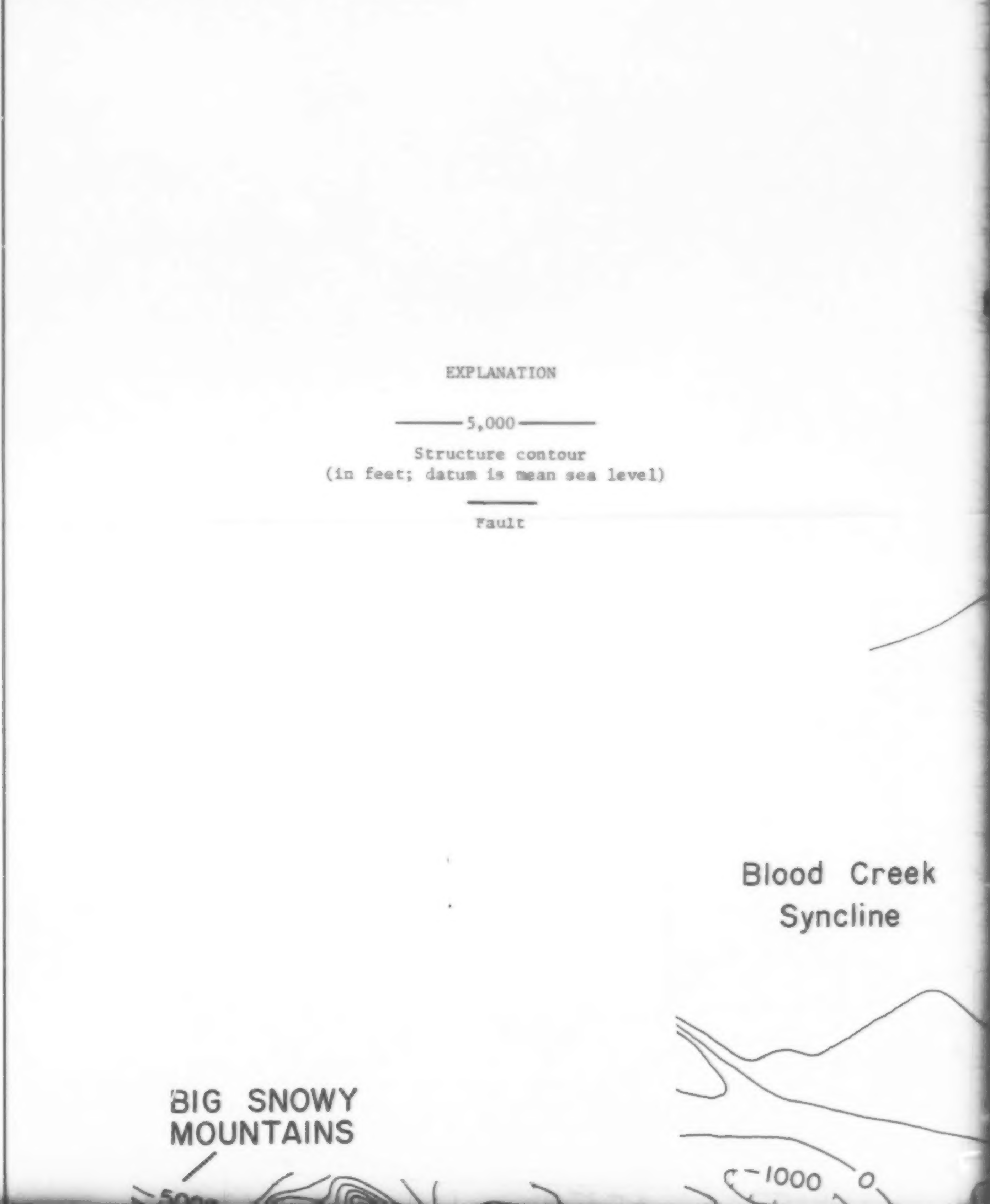


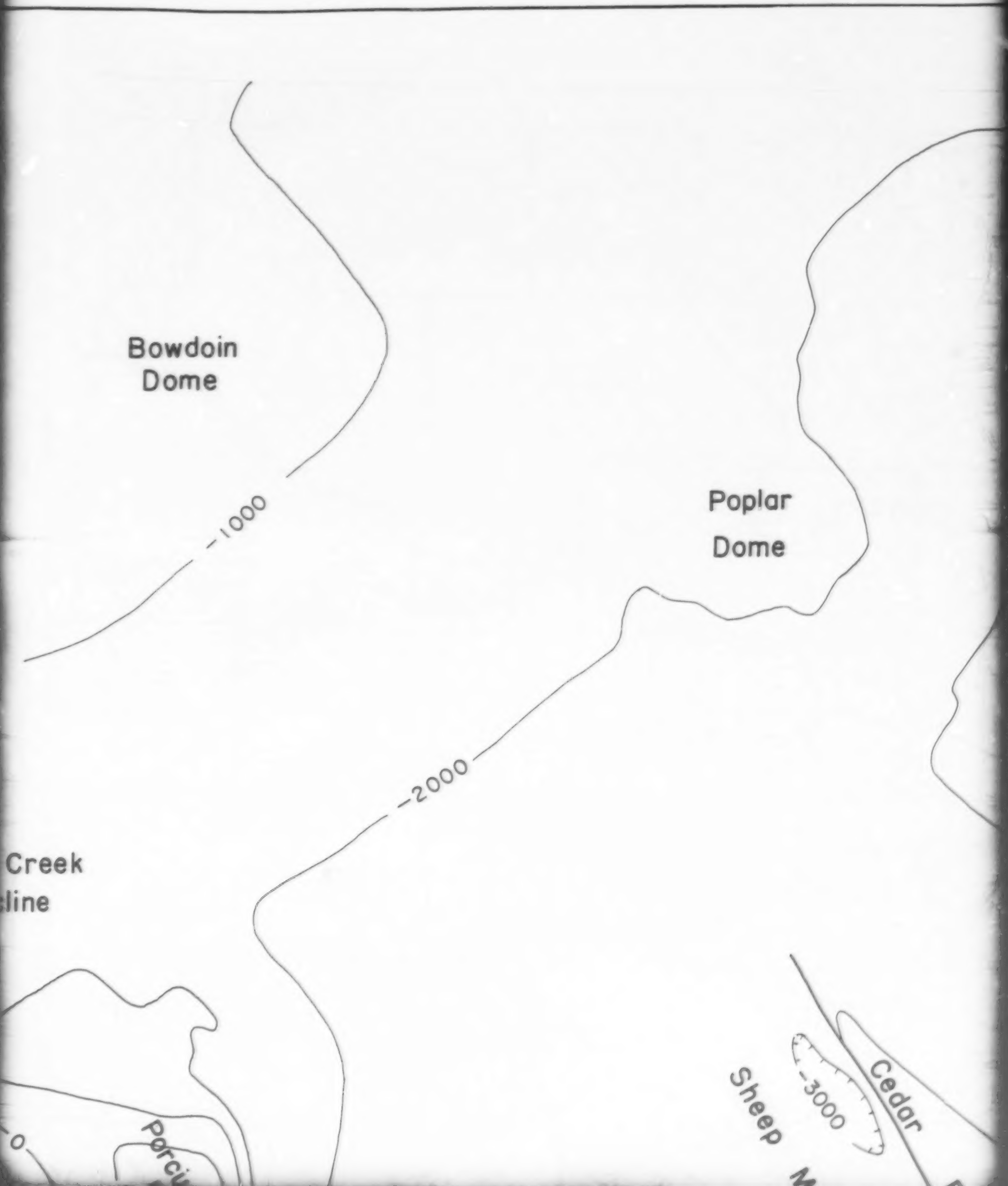
EXPLANATION

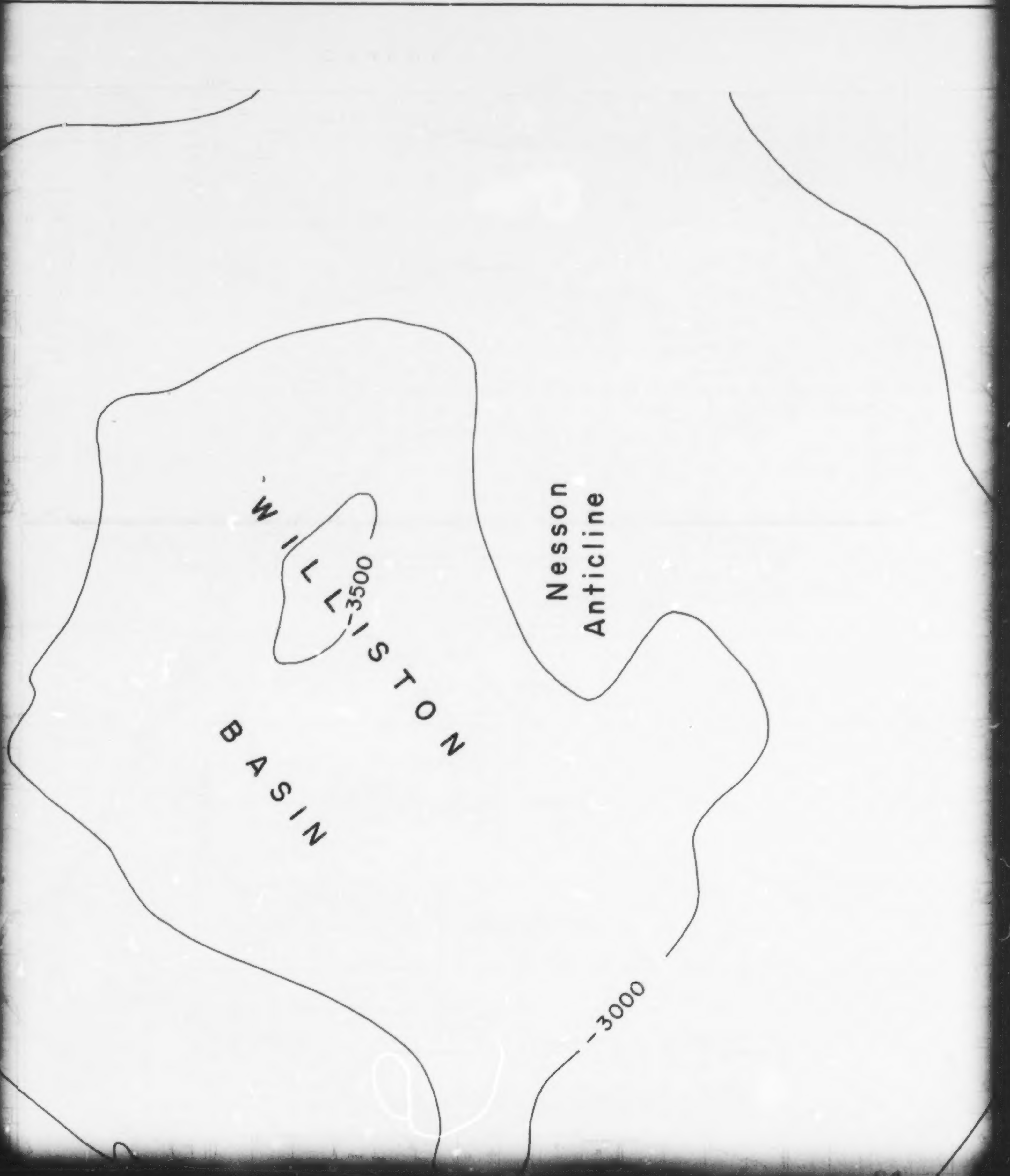
——5,000——

Structure contour
(in feet; datum is mean sea level)

——

Fault


Bowdoin Dome
-1000
Poplar Dome
-2000
Creek
line
-3000
Cedar
Sheep
M
0
Porci


WILLISTON
BASIN
Nesson
Anticline
-3500
-3000

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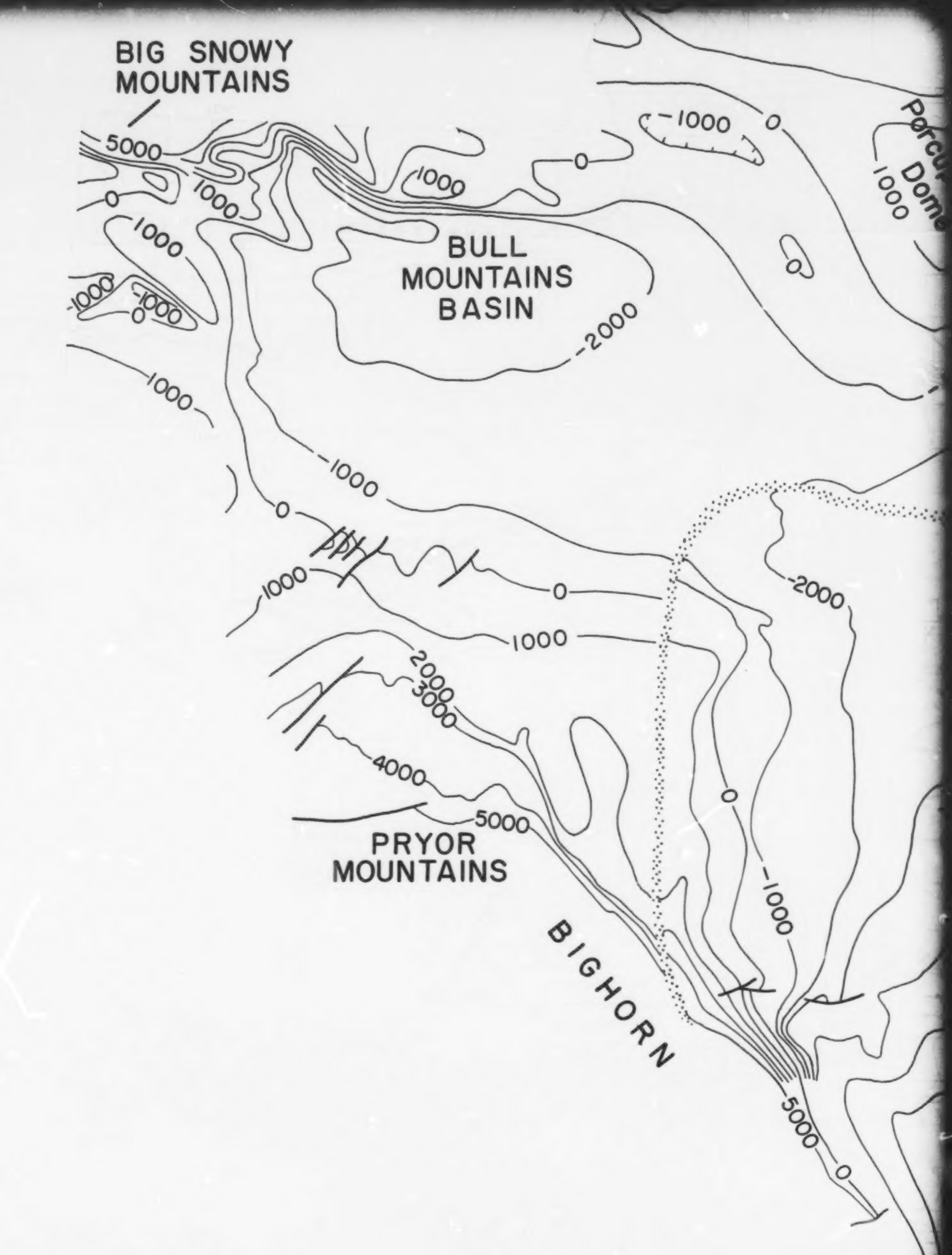
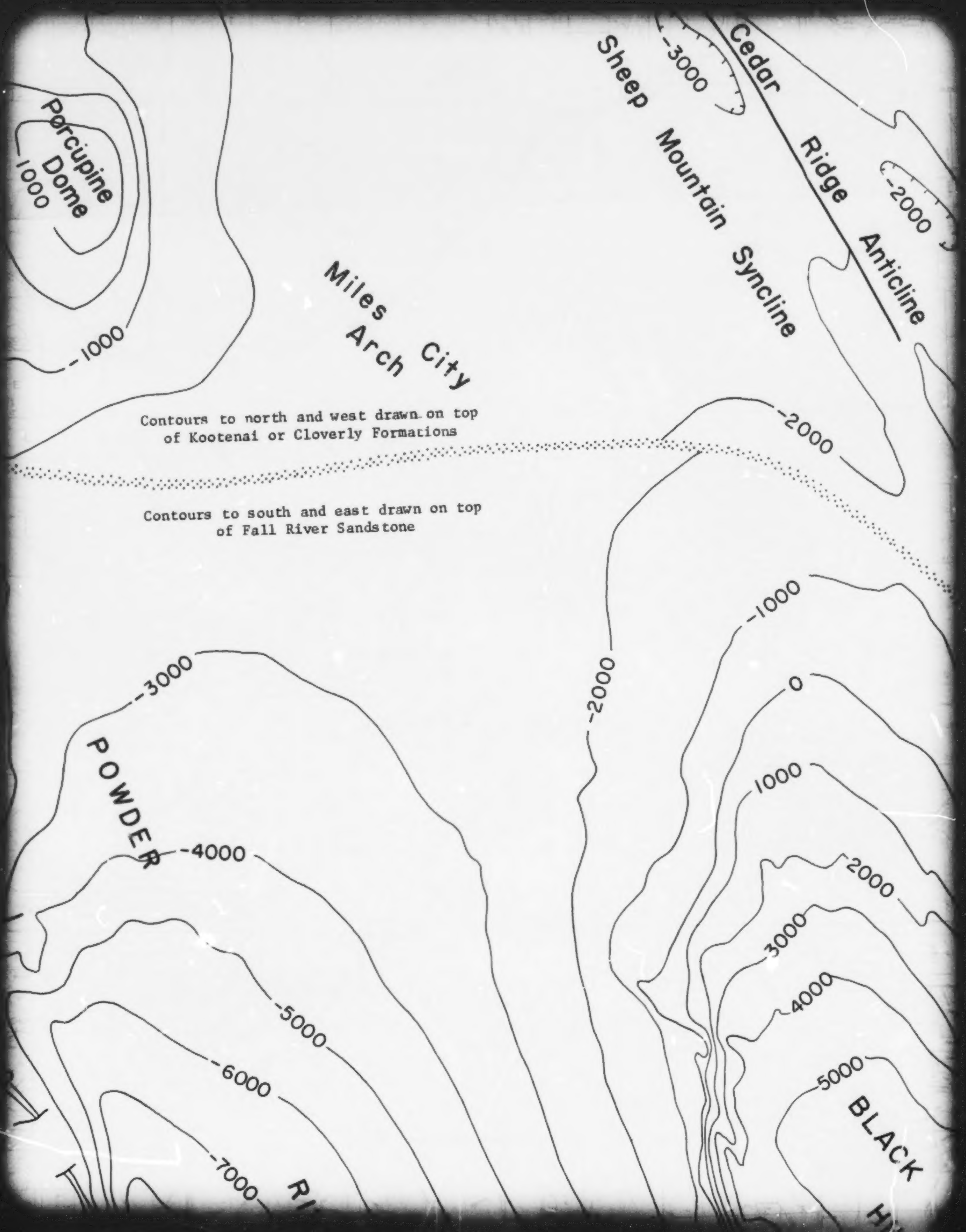


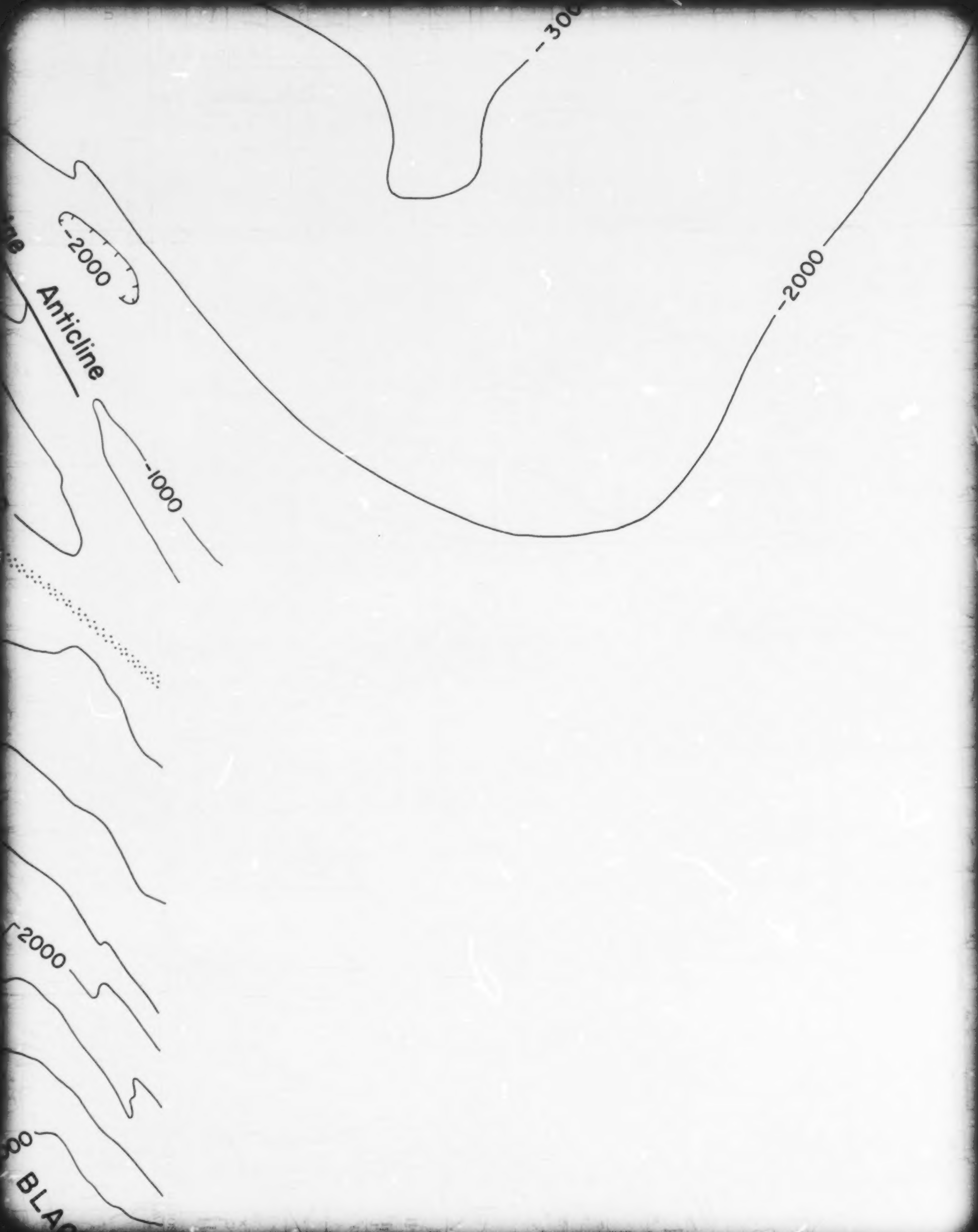
SOURCES OF DATA

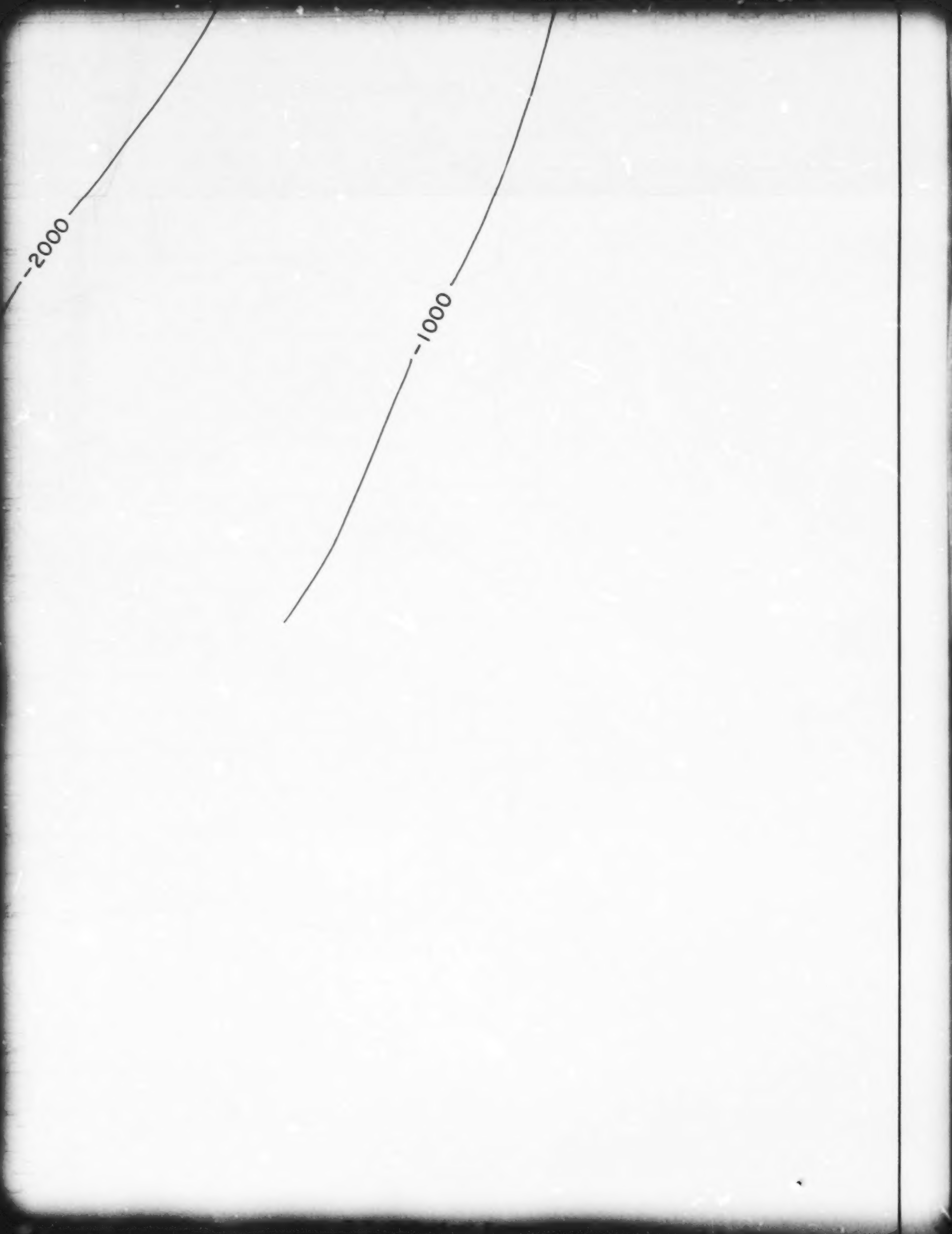
Barlow and Haun, Inc., 1969, Structure contour map

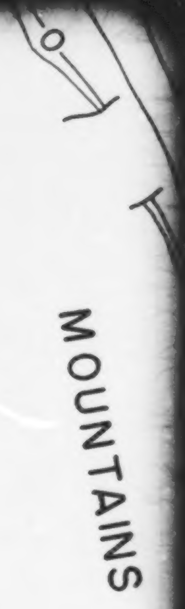


Contours to north and west drawn on top of Kootenai or Cloverly Formations

Contours to south and east drawn on top of Fall River Sandstone


-300
ine
-2000
Anticline
-1000
-2000
2000
00
BLAC


BURLEIGH
-2000
-1000



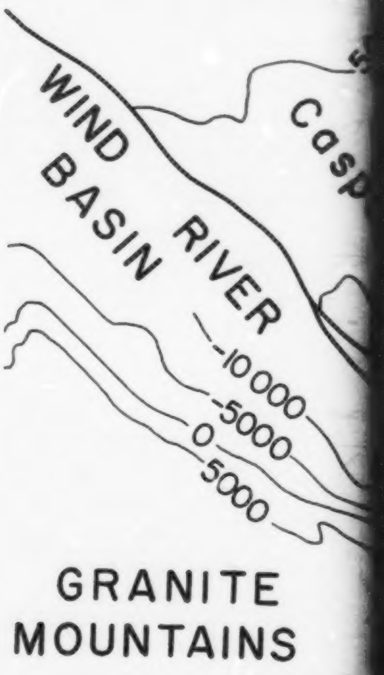
SOURCES OF DATA

Barlow and Haun, Inc., 1969, Structure contour map of Wyoming, northwestern Colorado, and northeastern Utah: Petroleum Ownership Map Co., Casper, Wyoming.

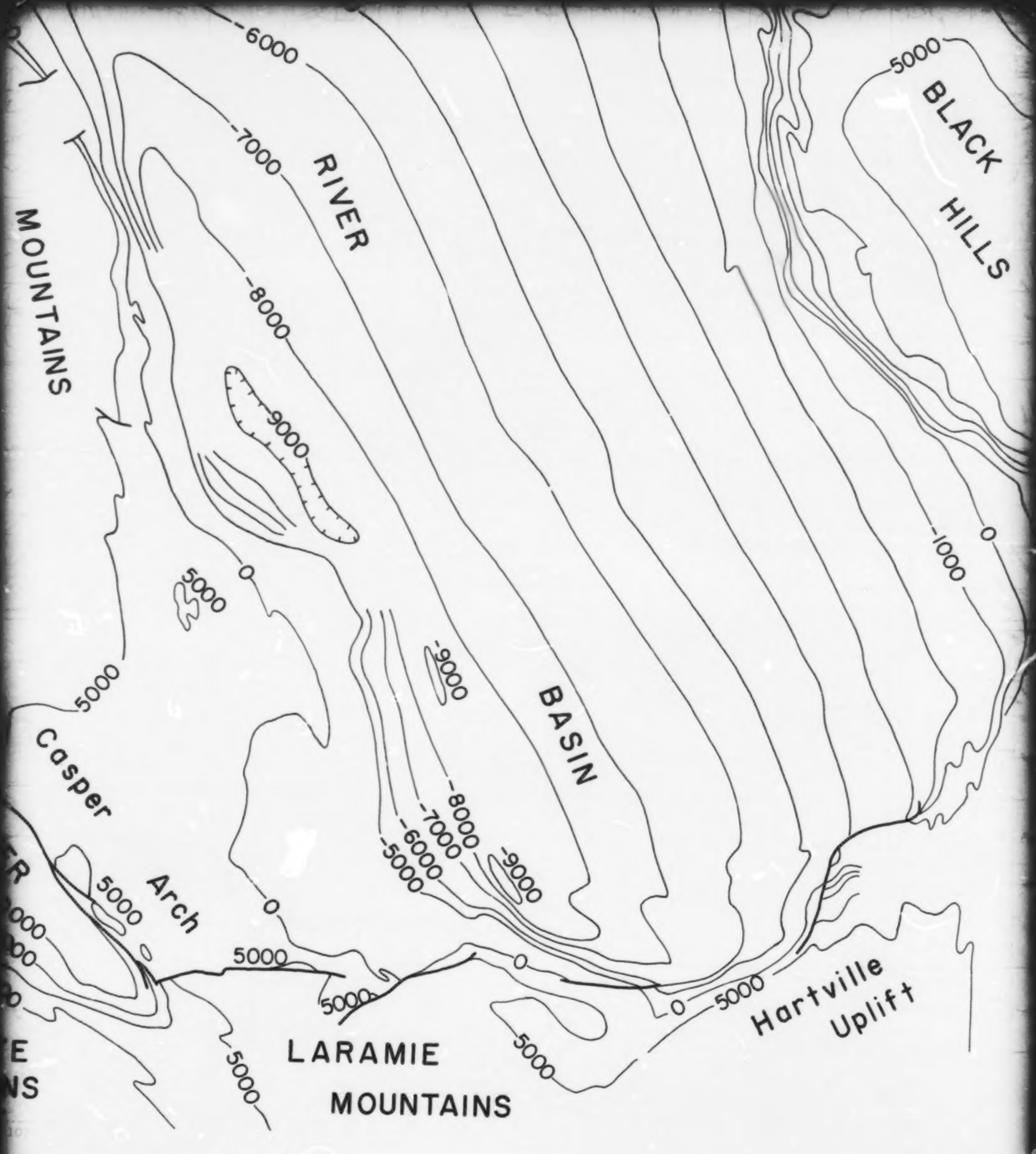
_____1973, Structure contour map of the Powder River Basin, Wyoming and Montana: Petroleum Ownership Map Co., Casper, Wyoming.

Dobbin, C. E., and Erdman, C. E., 1955, Structure contour map of the Montana plains: U.S. Geol. Survey Oil and Gas Inv. Map OM 178B.

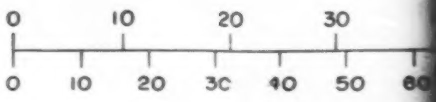
Sandberg, C. A., 1962, Geology of the Williston basin, North Dakota, Montana, and South Dakota, with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey TEI Report 809.



Base from U.S. Geological Survey
State base maps


6000
7000
RIVER
MOUNTAINS
8000
9000
5000
BLACK HILLS
0
-1000
0
5000
-9000
BASIN
5000
Casper
Arch
5000
0
-8000
-7000
-6000
-5000
-9000
0
5000
5000
0
5000
0
5000
Hartville Uplift
5000
5000
LARAMIE MOUNTAINS

SCALE 1:1 000 000



PLATE

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Prepared

THE NORTHERN GREAT PLAIN

By

William R.

U. S. Geological

1974

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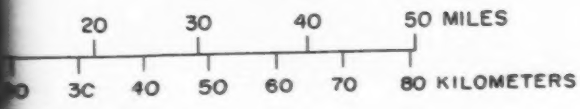
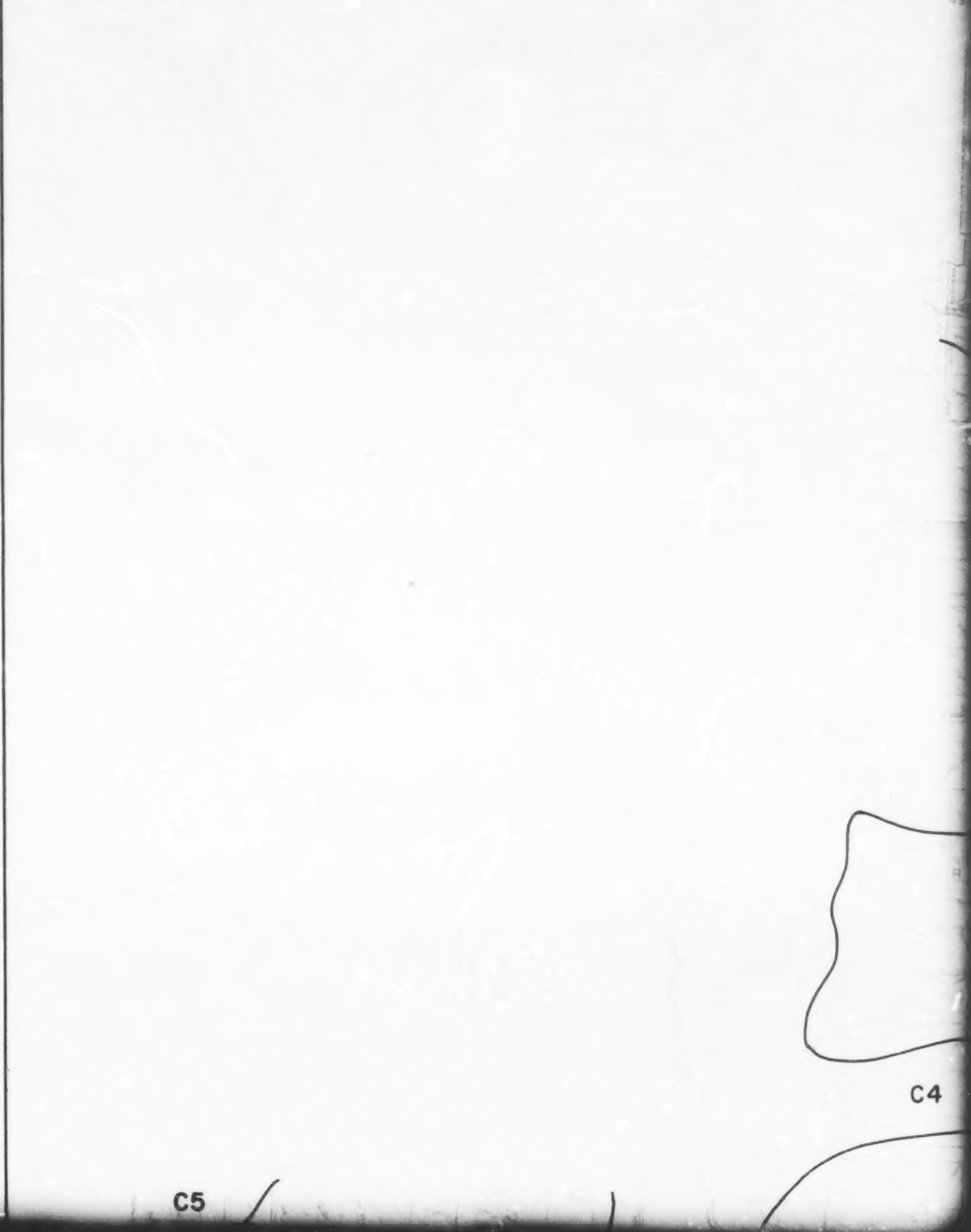


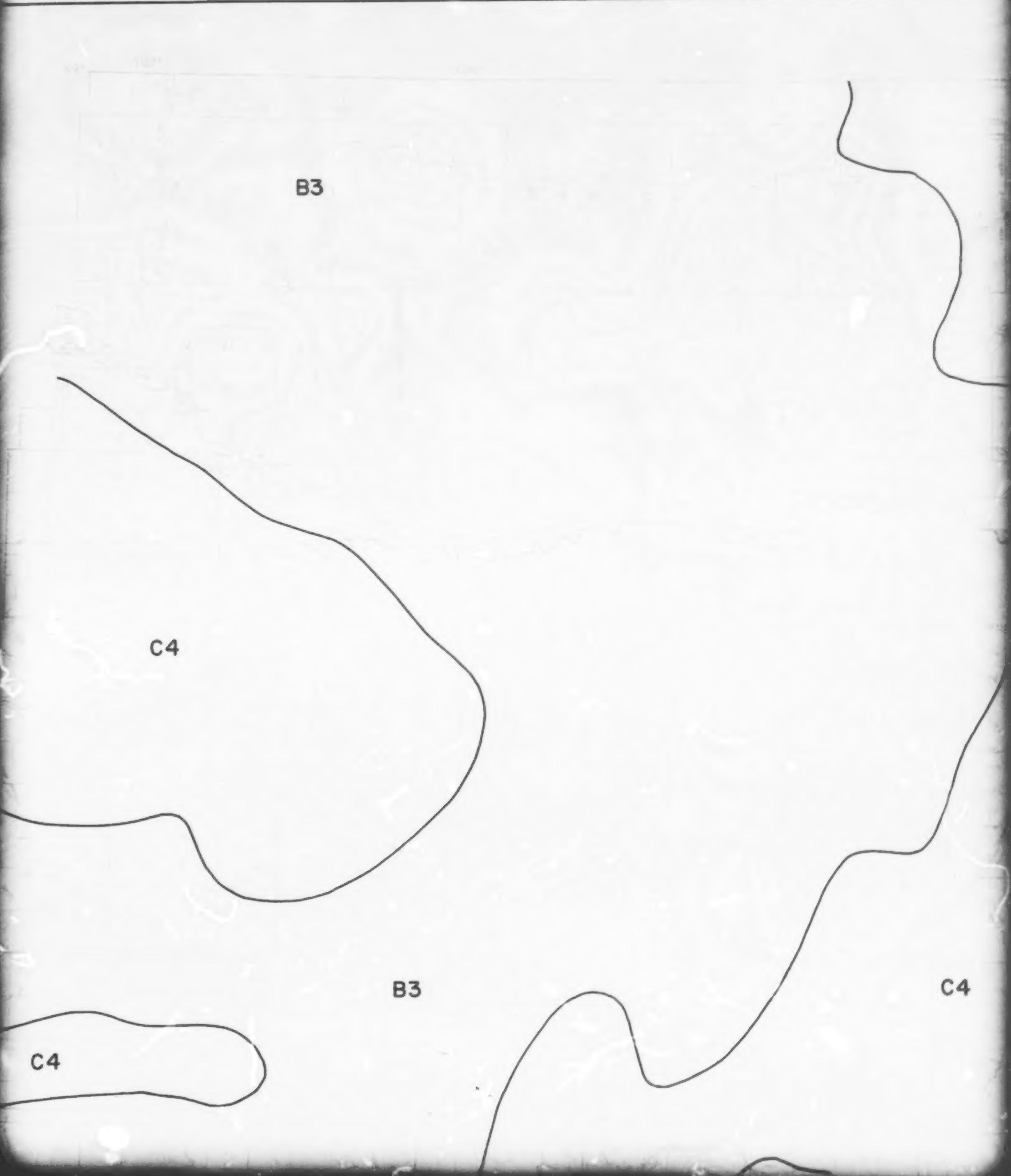
PLATE A-4

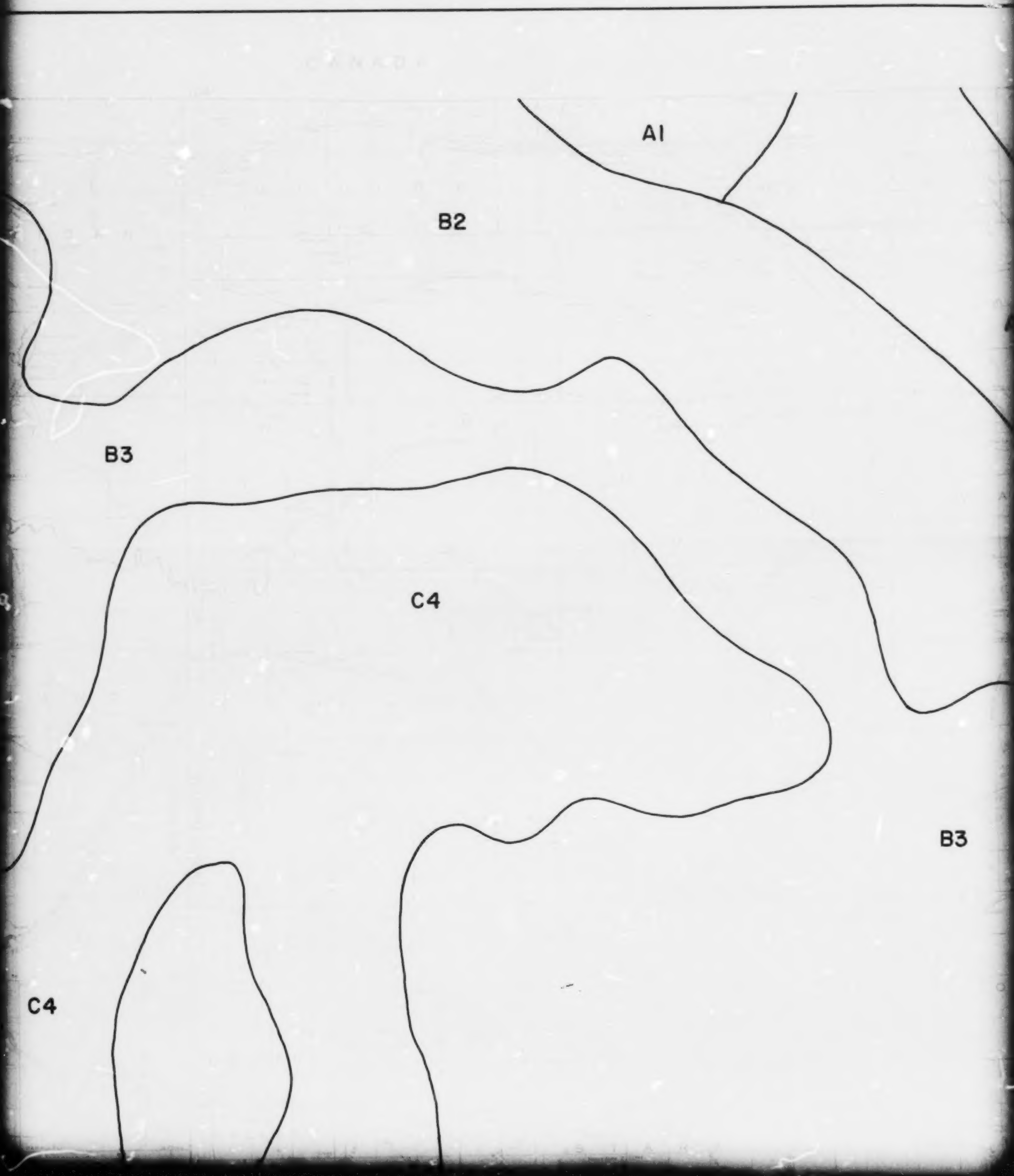
RE CONTOUR MAP OF THE
THERN GREAT PLAINS

Prepared for
GREAT PLAINS RESOURCES PROGRAM
By
William R. Keefer
U. S. Geological Survey
1974

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY




B3
C4
B3
C4
C4


A1
B2
B3
C4
B3
C4

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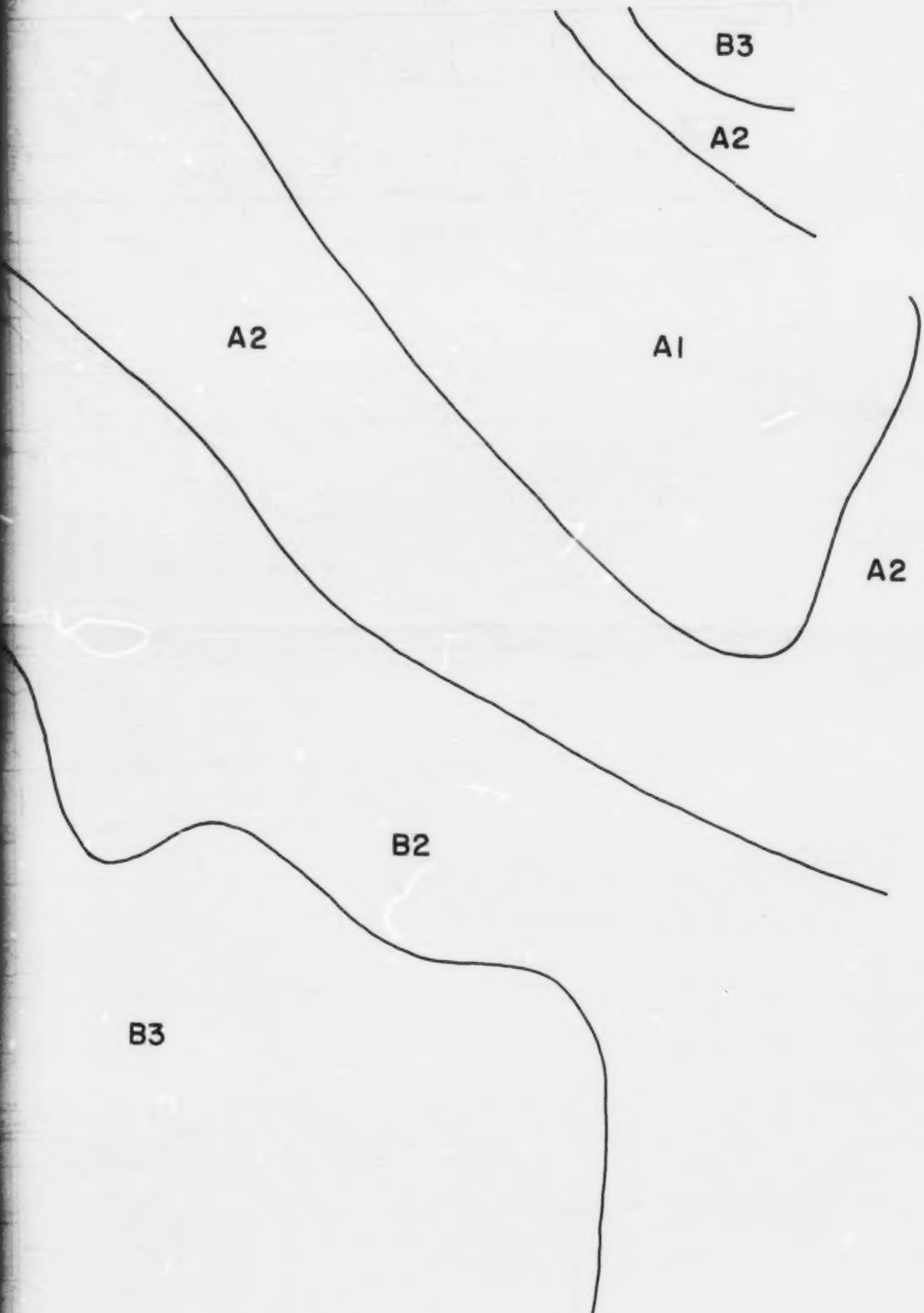
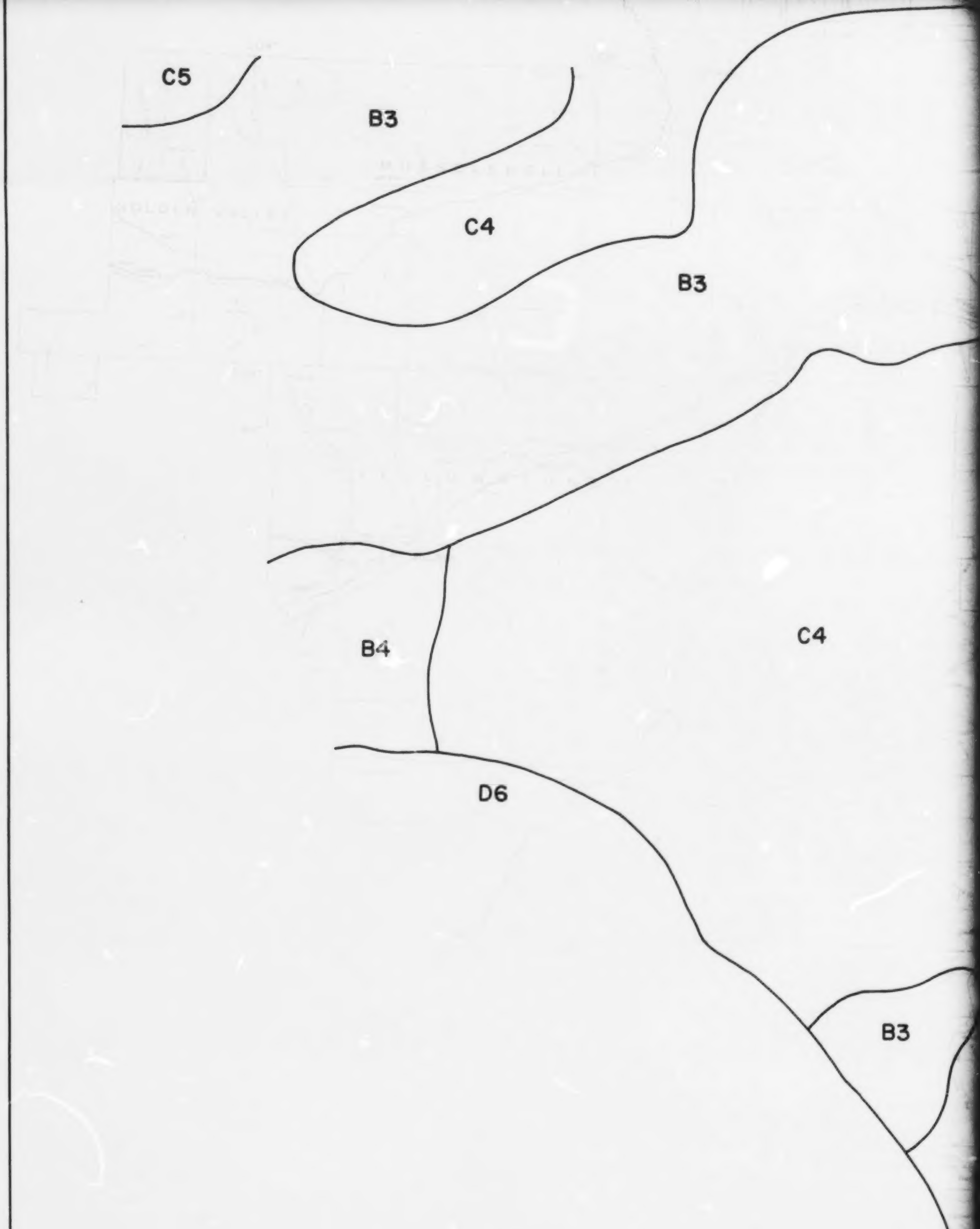
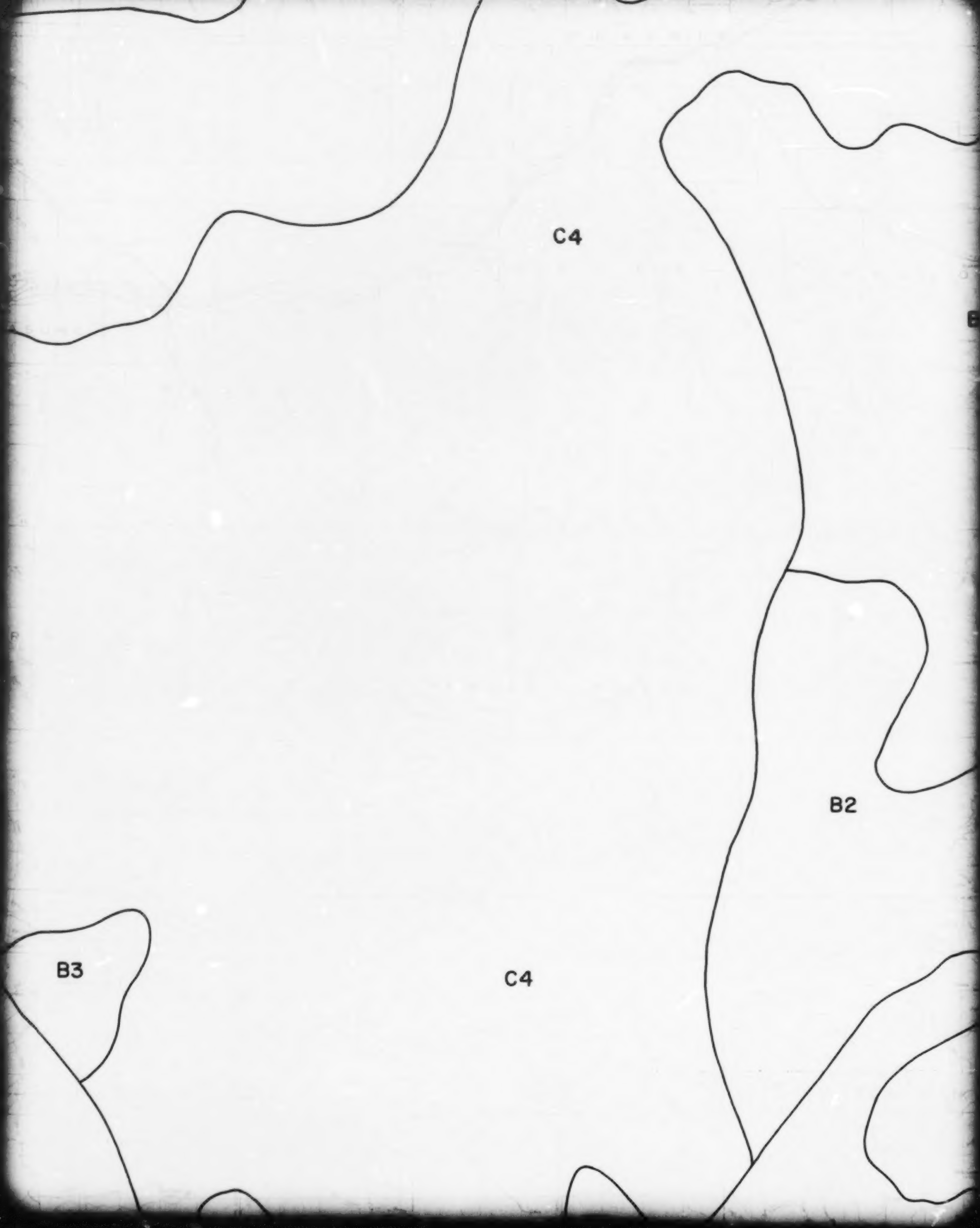
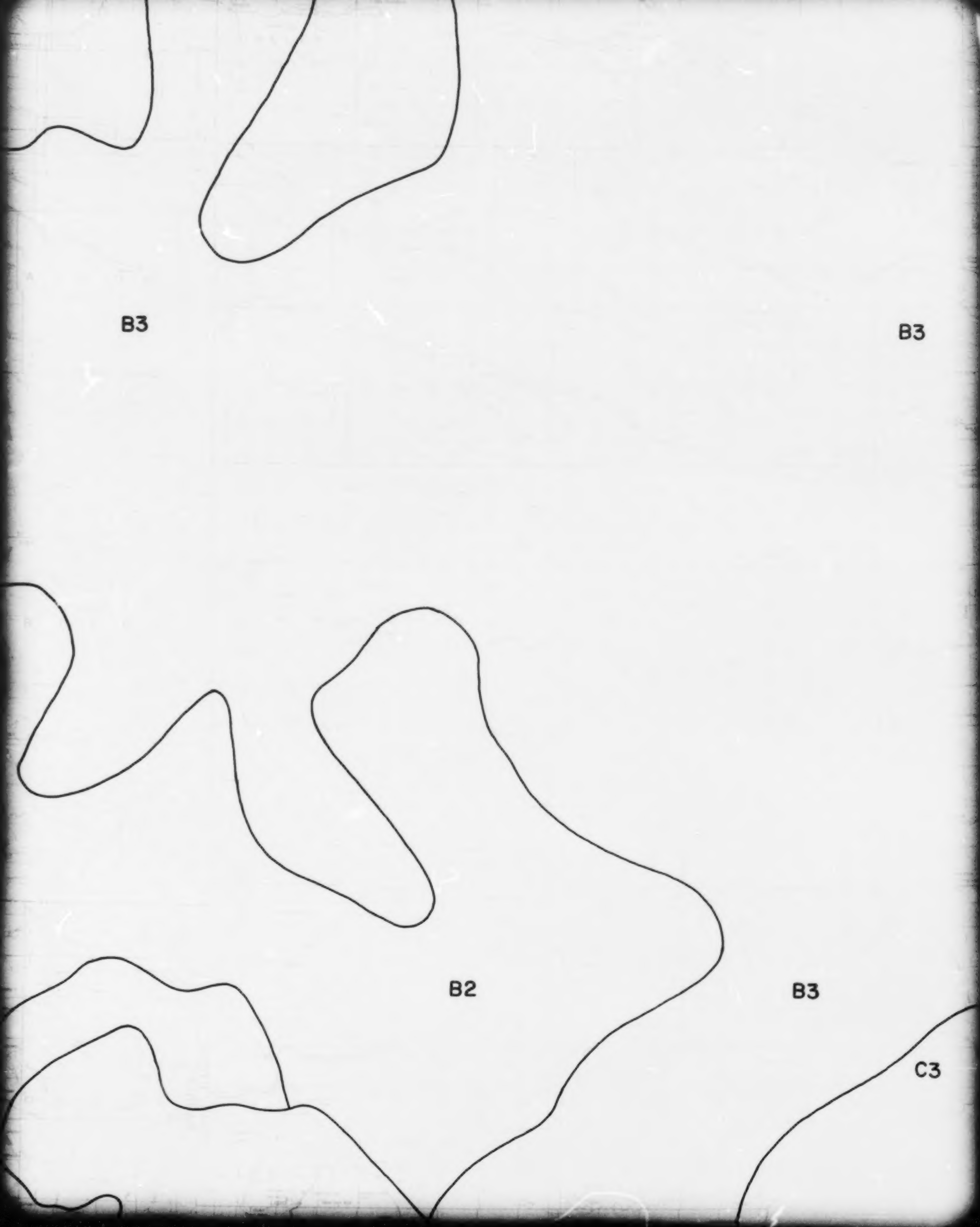


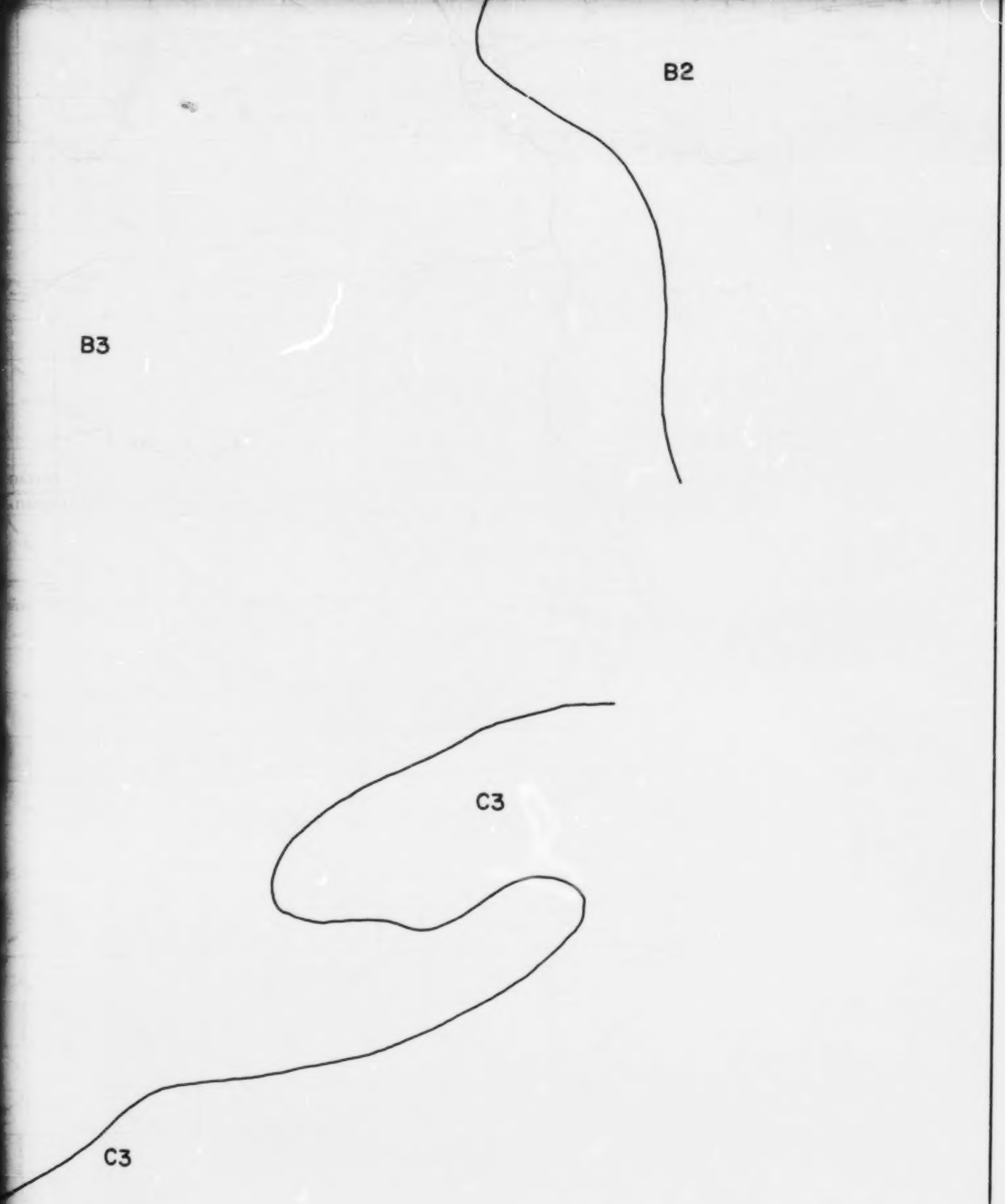


EXPLANATION

A1 Flat plains


C4
B
B2
B3
C4


B3
B3
B2
B3
C3



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EXPLANATION

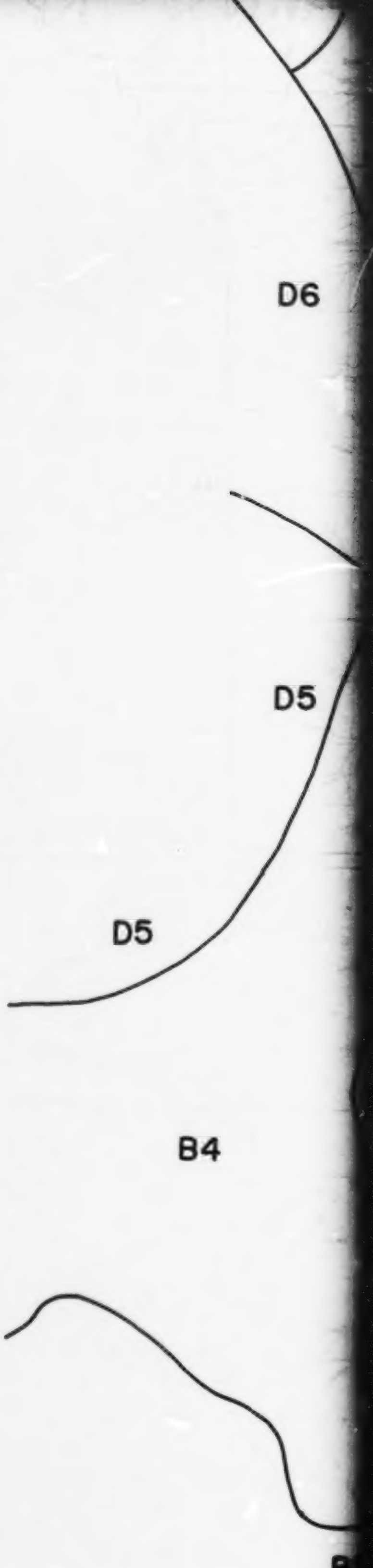
A1	Flat plains
A2	Smooth plains
B2	Irregular plains
B3	Plains and tablelands, moderate relief
B4	Plains with high hills
B5	Plains with low mountains
C3	Open hills
C4	Open high hills
C5	Open low mountains
D5	Low mountains
D6	High mountains

SLOPE

A	More than 80% of area gently sloping (slopes less than 8% or 4°35')
B	50-80% of area gently sloping
C	20-50% of area gently sloping
D	Less than 20% of area gently sloping

LOCAL RELIEF

1	0-100 feet
2	100-300 feet
3	300-500 feet
4	500-1,000 feet
5	1,000-3,000 feet
6	Over 3,000 feet



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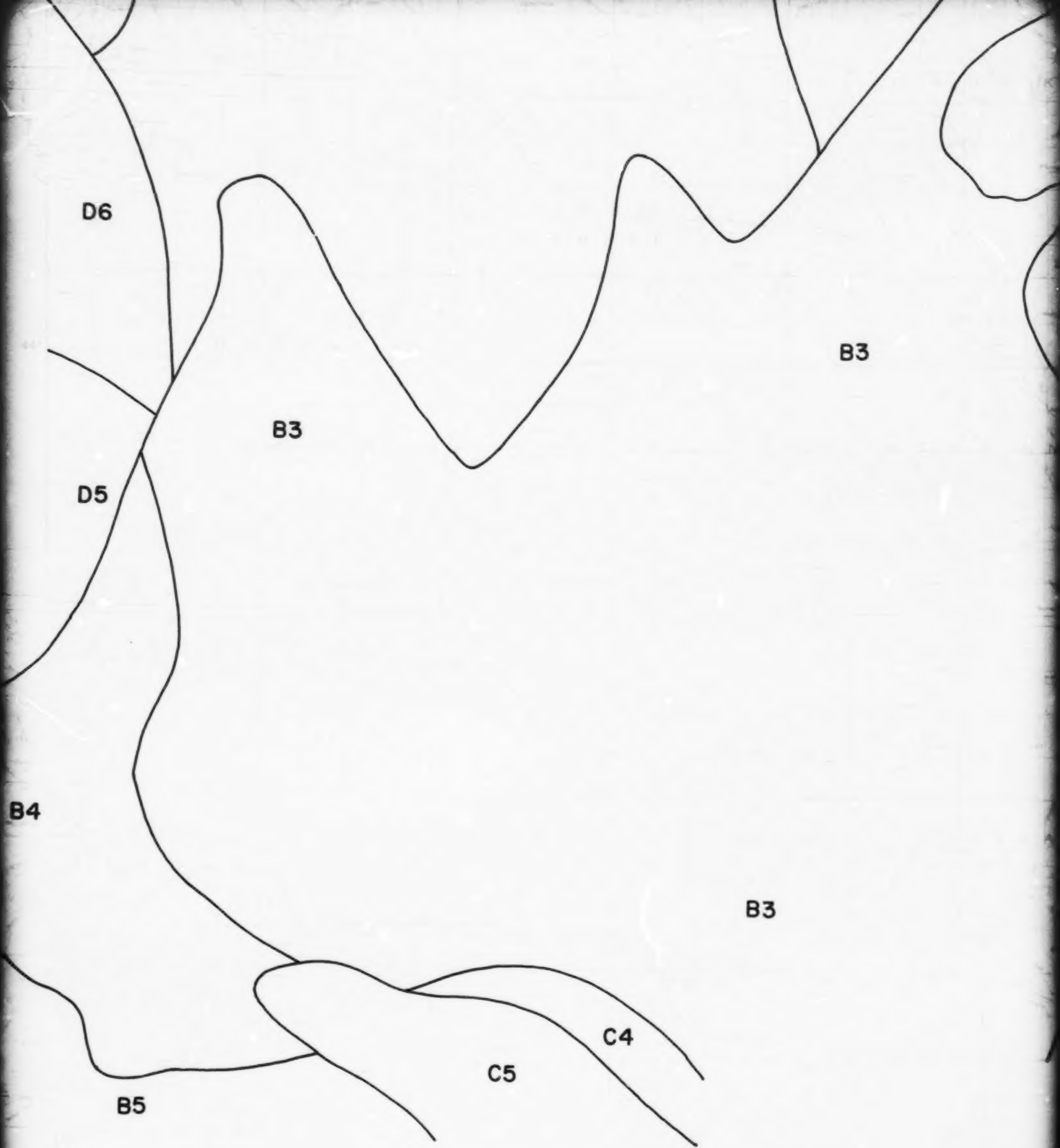
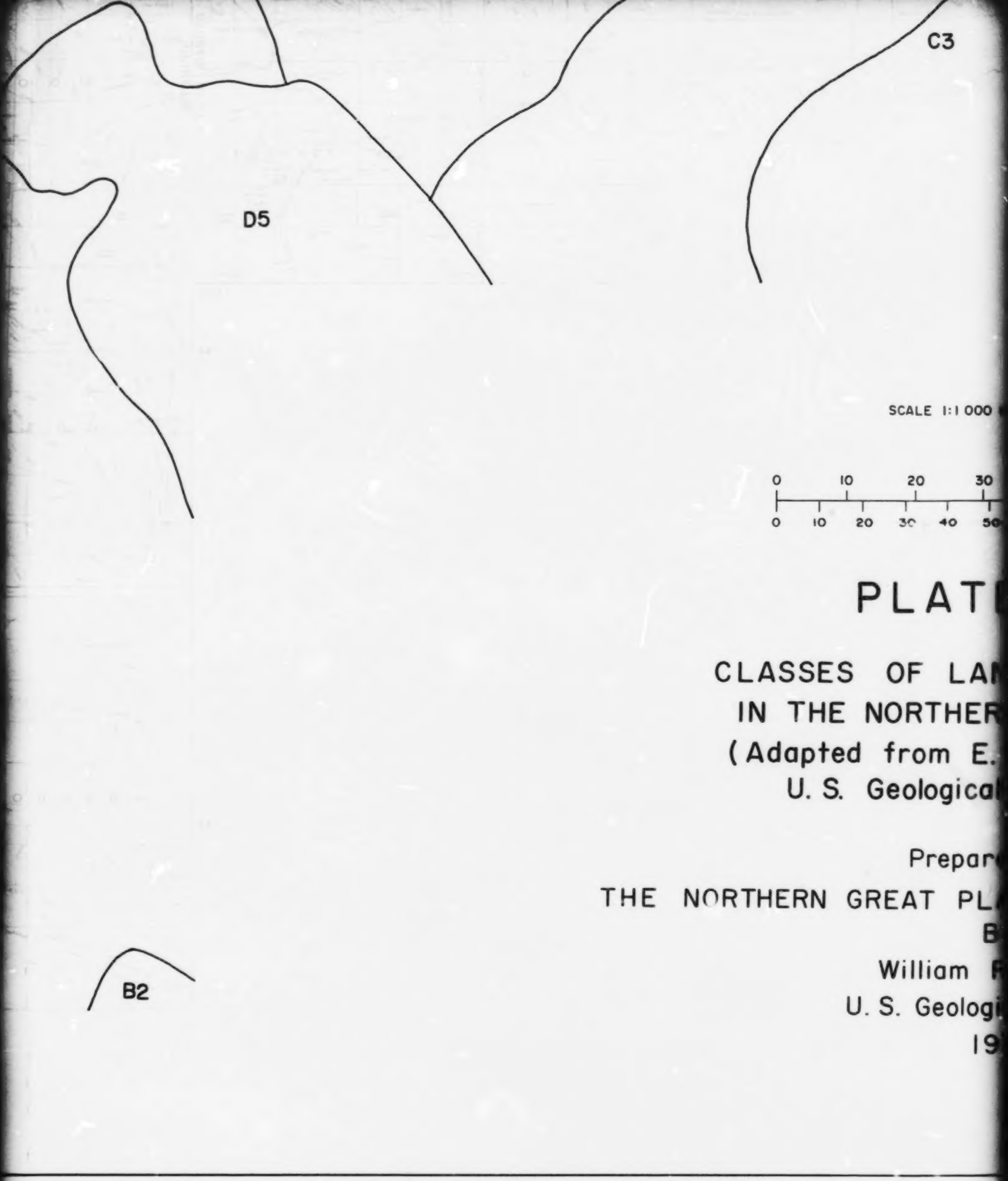
State base maps



Geological Survey



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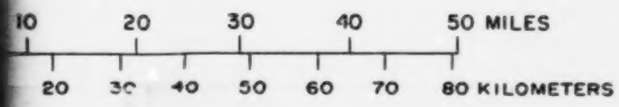

PLATE A-2

S OF LAND-SURFACE FORM
E NORTHERN GREAT PLAINS

ed from E. H. Hammond, 1964;
S. Geological Survey, 1970)

Prepared for
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By
William R. Keefer
U. S. Geological Survey
1974